MARCH, 1961

Welding Journal

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PRESS-TIME NEWS... about ...People ...Welding ...Products

New NCG Headquarters in California

A modern one-story building in Lynwood, Calif., that combines efficient office space and a large warehouse under its flat roof is the new Los Angeles headquarters of the National Cylinder Gas Div. of Chemetron Corp. The new structure is adjacent to an NCG plant which produces industrial and medical gases.

The building, started in July 1960, is constructed of concrete block and steel, and is decorated with plantings along the front wall. The company's western regional and Los Angeles district offices are in the front portion, a 40- by 80-ft unit with movable partitions. The warehouse portion of the building is in the rear and is of steel siding. The 80- by 100-ft area is used for storage of NCG medical and industrial apparatus and supplies.

The building will enable NCG to consolidate its Los Angeles office and storage facilities at one location near the gas plant according to C. E. Reese, regional manager.

CGA OFFICERS

Recently elected Compressed Gas Association officers. Left to right are D. M. Horner, R. S. Passmore, R. L. Swope and F. R. Fetherston

RWMA Reports 15% Rise in 1960 Shipments

Year-end figures compiled by the Resistance Welder Manufacturers' Association reveal that 1960 shipments were 15.4% above 1959. More than $29 million in resistance welding equipment was delivered to industry by RWMA Members last year.

New business and shipments for the month of December both showed slight increases over November.

Backlogs of nearly $9 3/4 million were reported by members at the end of the year.

CGA Elects New Officers

At the 48th Annual Meeting of the Compressed Gas Association, Inc., held Jan. 23–25, 1961, at the Waldorf-Astoria Hotel, New York, N. Y., the following were elected to office. D. M. Horner, president of Harrisburg Steel Co., and Taylor-Wharton Co., both being divisions of Harsco Corp., president; R. S. Passmore, manager, Ammonia Division, Armour Industrial Chemical Co., 1st vice president; and R. L. Swope, vice president, Southern Oxygen Co., 2nd vice president. Franklin R. Fetherston was re-elected secretary-treasurer of the association.

Missile Symposium

An open meeting with missile and rocket fabrication experts will highlight the gathering of more than 18,000 engineers, production personnel, research and development, and top management people at the AMERICAN WELDING SOCIETY 42nd Annual Meeting and Exposition, April 17–21, in New York City.

The symposium will be conducted by the AWS Missiles and Rockets Welded Fabrication Committee at 2 P.M. on Wednesday, April 19th, at the Commodore Hotel. The Committee, formed in September 1960 when guidance was vitally needed for our national defense program, consists of experts from most of the major companies banded together to pool their knowledge in a combined effort which has resulted in the solution of many difficult fabrication problems.

The symposium will be moderated by Donald B. Howard, chairman of the Committee and staff metallurgist, American Car and Foundry, ACF Industries, Inc., and with him will be Francis H. Stevenson, Aerojet-General Corp.; Byron Gates, Budd Co.; Donald W. Kinsey, U. S. Steel Corp.; Russell D. Libert, A. O. Smith Corp.; Joseph W. Jakubowski, General Electric Co.; and John F. Rudy, Armour Research Foundation.

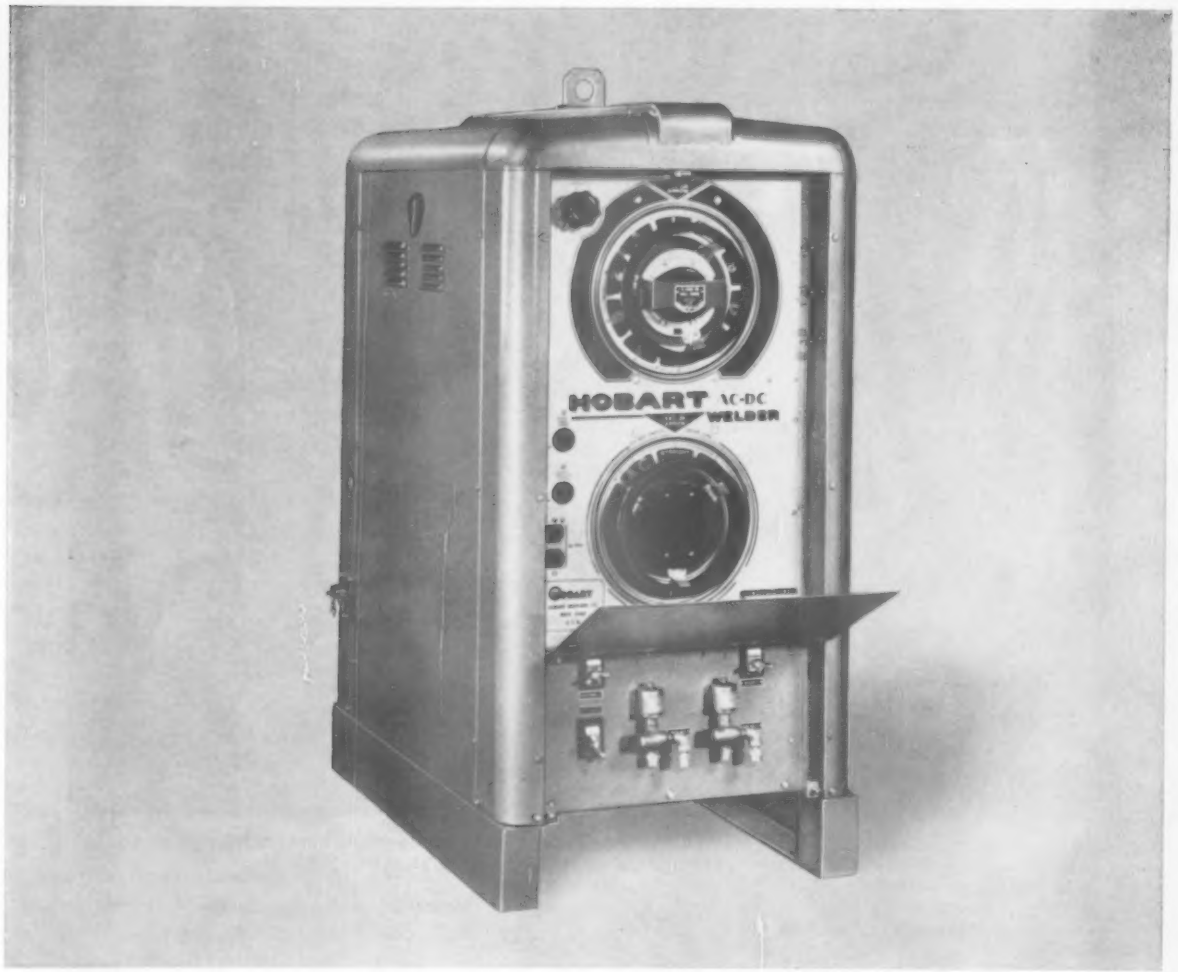
New NEMA Section for Unconventional Power Generation

Unconventional generation of electric power—a subject occupying the attention of all branches of industry and its top research scientists—is now focused in the National Electrical Manufacturers Association as a result of a meeting in New York City late in January by representatives of 22 leading member companies of NEMA.

Following the discussion, the companies decided to organize a new Unconventional Power Generation Section within the Association. The scope of this latest and by far the most advanced technical industry group to affiliate with NEMA will have the following products in its scope. magnetohydrodynamics (MHD), fuel cells, thermoelectrics, thermionics, batteries, photovoltaics and photochemicals.

A five-man program committee, headed by Dr. Manfred Altman, consulting engineer, Missile-space Vehicle Department, General Electric Co., was appointed to prepare recommendations to the section at an early date concerning proposed section activities. Early projects probably will deal with Government contacts and the development of standards for basic terms, definitions and tests.

It is expected that invitations will be extended, at an early date, to companies in this field which are not presently members of NEMA to join the Association and affiliate with the new Section.



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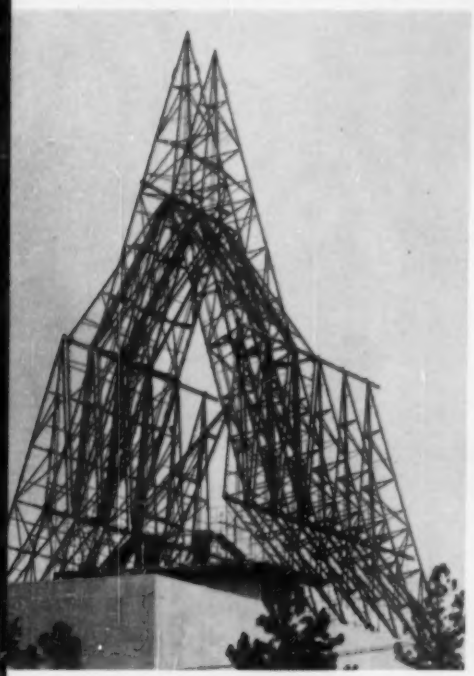
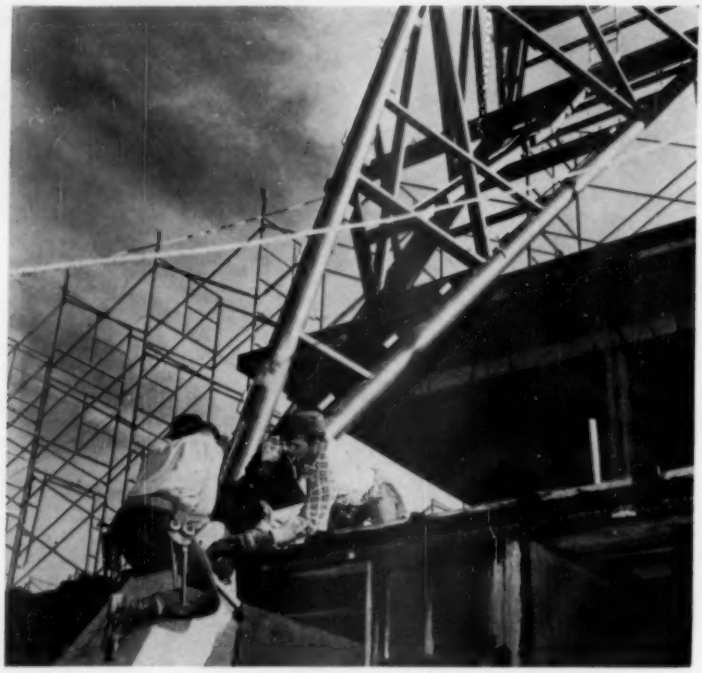
WELDING ZONES



One hundred tetrahedral-shaped supports made of steel pipe were erected to form the unique many-spired chapel at the U. S. Air Force Academy, Colorado Springs, Colo. (Courtesy Republic Steel Corp.)

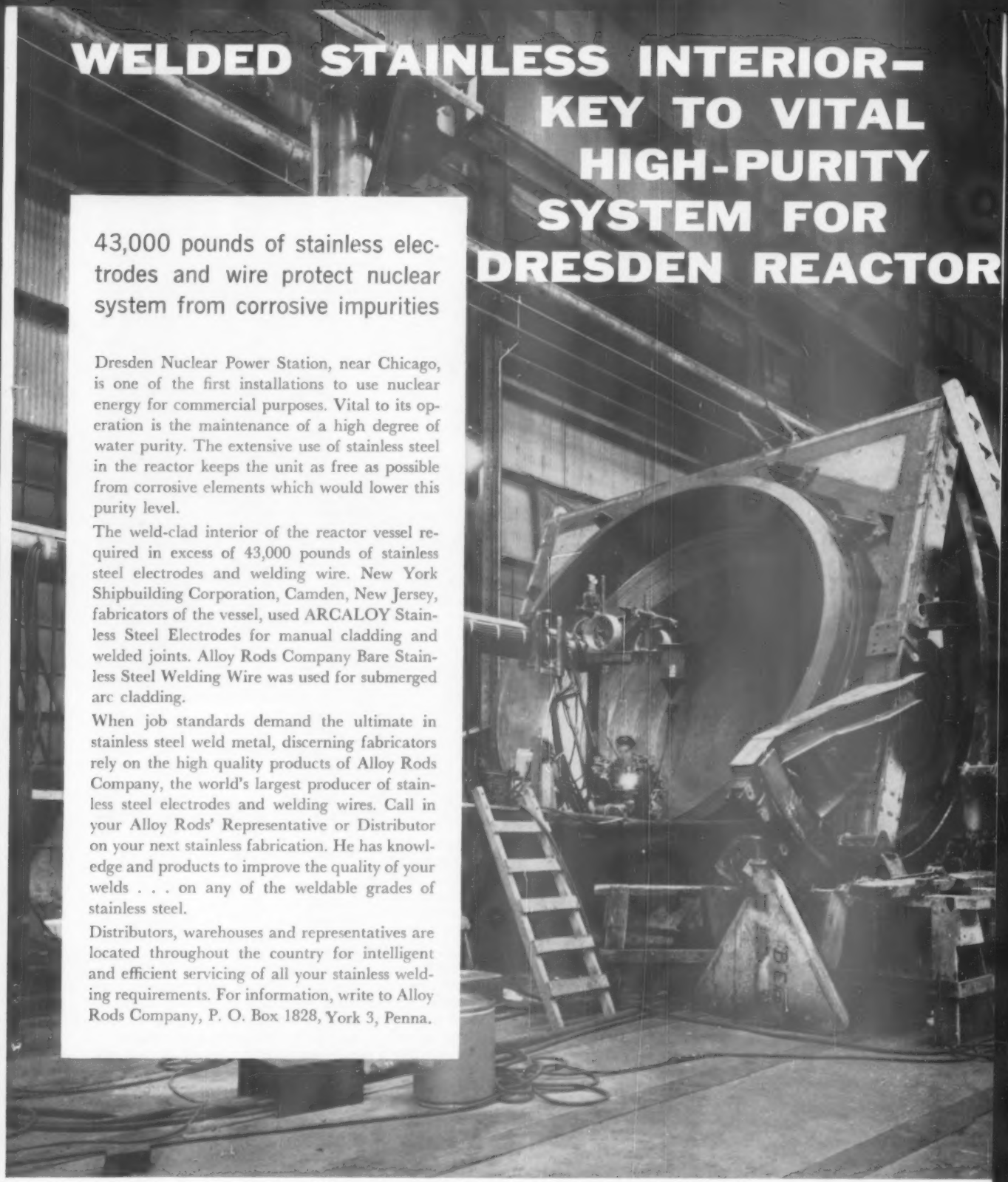


Men bolt the end of one tetrahedron, fabricated from welded steel pipe, into place at the Air Force Academy Chapel site. (Courtesy Republic Steel Corp.)

Semiautomatic welding of primary building blocks of aluminum elevators installed by the Newport News Shipbuilding and Dry Dock Co., on the USS Enterprise, largest ship in the world. (Courtesy Aluminum Co. of America)

Finishing touches put on first all-aluminum mine car manufactured by Irwin-Sensenich Corp., which will carry seven times its weight in payload. (Courtesy Aluminum Co. of America)

WELDED STAINLESS INTERIOR— KEY TO VITAL HIGH-PURITY SYSTEM FOR DRESDEN REACTOR



43,000 pounds of stainless electrodes and wire protect nuclear system from corrosive impurities

Dresden Nuclear Power Station, near Chicago, is one of the first installations to use nuclear energy for commercial purposes. Vital to its operation is the maintenance of a high degree of water purity. The extensive use of stainless steel in the reactor keeps the unit as free as possible from corrosive elements which would lower this purity level.

The weld-clad interior of the reactor vessel required in excess of 43,000 pounds of stainless steel electrodes and welding wire. New York Shipbuilding Corporation, Camden, New Jersey, fabricators of the vessel, used ARCALOY Stainless Steel Electrodes for manual cladding and welded joints. Alloy Rods Company Bare Stainless Steel Welding Wire was used for submerged arc cladding.

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WORLD-WIDE WELDING NEWS

By Gerard E. Claussen

BELGIUM

The Belgian magazine *Arcos* (issue no. 144, 1960) consisted of a 40-page description of electroslag welding using a cored electrode. Procedures are explained for circumferential joints, for restarting a weld and for surfacing. The slow progression of welding tends to avoid cracking and porosity, yet severely laminated plate may give rise to porosity. As-welded Charpy V impact values at −4° F were above 20 ft-lb for certain weld metals, in particular a weld containing 0.08 C, 1.44 Mn, 0.22 Si and 0.83 Ni. The process has been used in Western Europe for welding steel cylinders 3½ in. thick, shafting 8 in. diam and the circumferential joint of a hydraulic turbine, 10 in. thick.

DENMARK

The May 1960 issue of *Dansk Teknisk Tidskrift* reviews the Scandinavian Welding Conference held in Copenhagen, May 19, 20 and 21, 1960. It describes the products welded by a large number of Danish fabricators and shipyards.

THE NETHERLANDS

The May 1960 issue of the Netherlands welding magazine *Lastechniek* contains an article on welding at low pressures and in a vacuum. As the pressure was lowered from 1 to 0.17 atm, the arc voltage of a covered electrode rose 2 to 4 v and the melting rate increased 20 to 35%. However spatter loss rose from about 7% at 1 atm to 40% at 0.17 atm. An electron beam welder for operation in a high vacuum also was described. Another article in this issue reviewed the process and equipment for gas pressure welding pipes and concrete reinforcing bars.

Dr. GERARD E. CLAUSSEN is associated with Arcords Corporation, Sparrows Point, Md.

USSR

The Russian magazine *Svarachnoe Proizvodstvo* for March 1960 contains the following articles.

1. The proportion of copper in the weld metal in depositing a copper electrode 0.079 in. diam on mild steel increased from 50 to 90% as current was decreased from 600 to 300 amp, using submerged-arc flux. There was 5 to 10% more copper in the deposit on straight polarity than on reverse. In the range 5 to 55% copper, transverse cracks occurred in the deposit. Mild steel clad with copper is used for good corrosion resistance and electrical contact properties.

2. Horizontal butt welds were made in 4- to 7-in. steel plates in the vertical position by the CO_2 process with 1/16-in. wire containing 0.07 C, 0.90 Si, 1.83 Mn at 300–340 amp, 27–30 v. The impact transition temperature of the weld metal was below −60° F.

3. Fatigue tests on fillet-welded steel specimens showed that axial stress fatigue strength was 14% higher after welding than after stress relief at 1200° F. Cold work by stretching or rolling raised the fatigue strength.

4. The maximum strength of ultrasonic welds in aluminum (Al – 6% Mg) alloy, and duralumin was achieved at 15 to 20 kc and a welding time of 1 to 2.5 sec with a load of 175 lb. The spherical tip was 3/8-in. radius. The strength per weld rose from 117 to 330 lb as the thickness of the aluminum sheet was increased from 0.019 to 0.059 in. Up to 550 lb per spot was secured in duralumin.

5. Welding speeds in submerged-arc welding surface beads on a steel cylinder 16½ in. diam were increased from 100 to 175 ipm by preheating to 1380–1475° F. The electrode was 5/32 in. diam and was deposited at 950 amp. Preheat prevented undercut at the sides of the bead.

6. The stress distribution in a spot-welded lap joint under load was shown by a theoretical analysis to involve a maximum stress at the spot 1.87 times the nominal stress.

7. The addition of 1% graphite to a MnO–SiO_2 submerged-arc flux raised the total hydrogen content of the mild steel deposit from 7.3 to 9.8 cu cm/100 g, but lowered the oxygen content from 69 to 41 and the nitrogen content from 7.8 to 4.6 cu cm/100 g. Graphite lowered the tendency for porosity with damp flux, while aluminum increased this tendency. The gaseous product of oxidation of graphite flushes hydrogen from the weld, while the solid product of oxidation of aluminum exerts no flushing action and promotes hydrogen porosity.

8. Electroslag welds were made in Type 321 austenitic stainless steel 2½ in. thick with a Type 321 electrode and a flux containing 35 Al_2O_3, 25 CaO, 40 CaF_2 with an addition of 1% Al. The weld metal contained 0.58 Ti.

9. Cotton cultivator plows are hard surfaced in production by submerged-arc welding. Alloys containing 4.5 C, 17 Cr, 8 Mn (51–54 Rockwell) are deposited by supplying the metallic alloys from a dispenser below the level of the flux and just in front of the arc. A mild steel electrode 0.079 in. diam is used at 350–400 amp with an oscillation of 1/4 in. per sec and flux containing 22 SiO_2, 28 Al_2O_3, 9 CaO, 18 MgO, 18 CaO, 7 NA_2O.

10. Submerged-arc hard surfacing is accomplished with a tape electrode consisting of a flat corrugated tube filled with alloying metals. The tape is formed from two mild steel strips, and is filled with alloys at the welding machine.

11. An argon-hydrogen mixture (27% argon) is used to cut aluminum with the plasma-arc torch and alternating current.

12. Designs are given for several high-tensile steel and titanium parts

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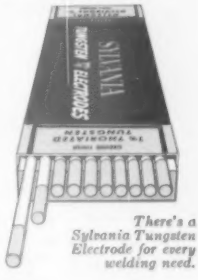

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for projection welding.

13. A machine for seam welding circumferential joints in stainless-steel tubing $^3/_8$ to $^7/_8$ in. diam 0.024–0.079-in. wall. A lap joint is employed with an inner mandrel. The assembly is rotated between the electrode wheels.

Automatic Welding

Highlights of papers in the March 1960 issue of the Russian automatic welding magazine *Avtomaticheskaya Svarka.*

1. A rectifier has been designed which is suitable for automatic and semiautomatic gas-shielded arc welding and for manual welding with covered electrodes. The rectifier consists of a main transformer, booster transformers, stabilizing reactor, arc-starting transformer and rectifier, and fan. Means are provided for controlling voltage wave shape.

2. To weld a corrosion- and wear-resistant steel for hydraulic turbines containing 0.10 C, 3 Mn, 20 Cr, 3 Ni, 2 Cu, a powder-core electrode wire is deposited with CO_2. The weld metal has the same composition as base metal and must contain at least 30% austenite to secure adequate hardness, 250 Vickers.

3. Of several wires tested for the submerged arc welding of Type 321 austentitic stainless steel, two provided the best corrosion resistance: one contained 1% V, the other contained 0.6 V, 0.6 Cb. Both weld metals contained 0.25 Ti.

4. The power factor of a 3-phase spot welding machine operating on 10 cycles was found to be higher than that of a single-phase machine operating on 50 cycles. Power factor depended on the firing angle of the ignitrons.

5. The creep strength and microstructure were reported for three weld metals of the type: 0.10 C, 20 Cr, 10 Ni. The highest strength metal also contained 1 Mo, 1 Cb, and had strength of 25,000 psi at 1200° F, 100,000 hr. An austenitizing heat treatment improved the strength of one weld metal, while a sigmatizing treatment did not reduce the ductility of another.

6. Notch tensile specimens of steel $^1/_2$ in. thick tested at room temperature showed no loss in strength when residual stresses up to the yield strength were present. At −58° F any effect on strength due to residual stresses was difficult to detect.

7. Air temperatures down to −40° F during welding were found to have no effect on the microstructure tensile strength, ductility and notch impact value of electroslag welds in mild steel and 0.3 Cr, 0.35 Ni steel $1^1/_8$ in. thick.

8. Intergranular corrosion in 17% Cr steel welded with austenitic electrodes occurred in a narrow zone extending a short distance from the fusion line into the base metal. The corrodant was 50% nitric acid at 230° F. The intergranular corrosion was reduced by adding Ti, Ta or Co to the steel.

9. A device is described for lining up the edges of pipe for cross country lines preparatory to tacking.

10. A plasma-arc torch was used to weld $^3/_4$-in. steel plate without edge preparation in a single pass. Argon−5% hyrogen mixture was the shielding medium and a small amount of filler wire was added to the weld.

11. A differential vacuum dilatometer was used for investigating phase changes in welded joints in titanium alloys.

WEST GERMANY

In its March 1960 issue the West German magazine *Schweissen und Schneiden* contains the following articles:

1. In a discussion of welding and cutting by means of a beam of electrons, an apparatus built in 1949 is described. The apparatus welded stainless-steel sheets 0.02 in. thick and drilled a neat hole 0.008 in. diam in the sheet. Recent work in butt welding alloy steel $^5/_8$ in. thick at 2.4 kw at a travel speed of 7 ipm showed that the weld was only 0.06 in. wide at the surface. The melting zone was found to propagate rapidly in the direction of the electron beam at high power inputs.

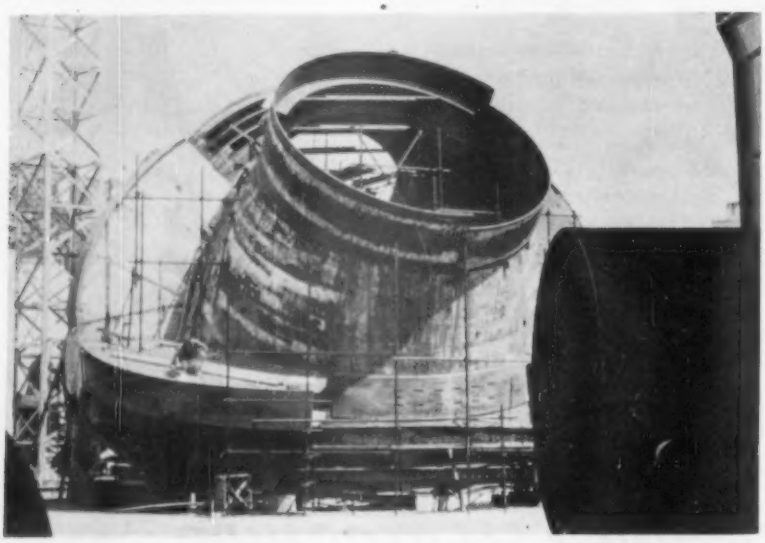
2. The fatigue strength of butt welds made with low hydrogen electrodes was 47,000 psi with dry electrodes but only 28,500 psi with damp electrodes. Fish-eyes appeared around the porosity in the fractures of specimens made with damp electrodes. Heating the welds made with damp electrodes to lower the hydrogen content to the same level as with dry electrodes did not raise the fatigue strength above 28,500 psi, but prevented fish-eyes. Tests on hydrogen-charged unwelded steel showed that hydrogen had little if any effect on fatigue strength unless the steel was elongated 10% before the fatigue test. After being elongated the uncharged specimens had a fatigue strength of 55,000 psi, compared with 46,000 psi for the hydrogen-charged specimens.

3. A useful review is given of the characteristics of automatic welding processes, including thermal and melting rate factors and bead geometry.

4. A moving scale for the illuminated face of an ultrasonic defectoscope is described to permit reading the depth of the defect directly.

5. German Standard DIN 8522 defines terms used in gas welding, gas cutting and other flame processes.

ITALY



Penstock fabricated by welding in Brecia, Italy. (Courtesy Linde Co.)

EUTECTIC's Report on the State of the Arc: CAST IRON

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Welding—A Bridge Spanning Frontiers and Oceans

As in other scientific and technical fields it can be seen that tremendous progress has also been made in the field of Welding Technology. Today, the manufacture of metal goods is entirely dominated by welding, whether it is a question of small utility goods for domestic use or large-scale structures for industry and communication. Present day supertankers, the modern enormous bridges and the equipment for nuclear power plants are only a few examples of the tremendous number of steel and metal structures, the fabrication of which is entirely dependent on welding. Indeed the fabrication of some of the components used in nuclear power plants and other large constructions would not be possible without the highly developed welding techniques now in common use.

The difficulties in disseminating this knowledge widely for general use have also been overcome to a certain degree. By the foundation of the International Institute of Welding in Brussels in 1948 we have an instrument which has this very mission as its main task. By means of the IIW and its activities, welding has bridged many frontiers and led to an increased understanding and cooperation between the nations of the world which must be to the advantage of all people.

The AMERICAN WELDING SOCIETY through its delegates has already given ample evidence of its interest in the activities of IIW. The American contributions are particularly important to the IIW because of the advanced techniques and extensive application of welding in this country. It was, therefore, with great pleasure that we accepted the invitation of the AWS to hold the Annual Assembly of the IIW in New York this year. The meeting is to take place in April—National Welded Products Month—conjointly with the 42nd Annual Meeting and Welding Exhibition of the AWS.

I sincerely hope that this united effort will be successful in producing results which are not only of importance for welded products but also for the strengthening of the bond of friendship between all the visiting participants in IIW and their American colleagues. Such a result would prove that welding has bridged oceans as well as frontiers.

Walter Edström

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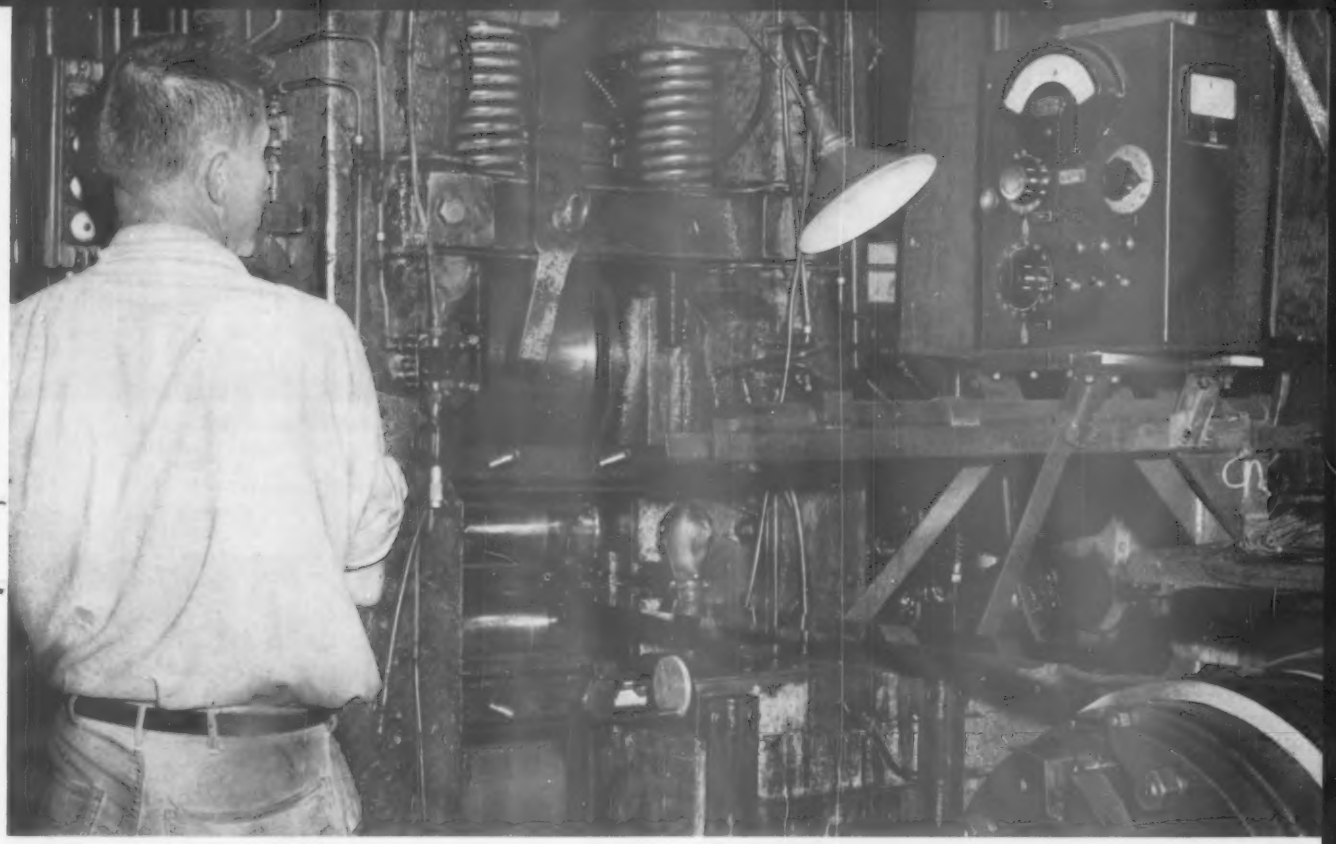


Fig 1—X-ray machine, installed in production line, checks dimensional uniformity of stainless steel strip

General survey and applications of probing media used in non-destructive weld tests wherein it is argued that

Nondestructive Testing Is Key to Future of Welding

Quality Control

BY GLENN J. GIBSON

Nondestructive testing is a fast growing science with many potential applications in the field of welding quality control.

More emphasis than ever before is being placed on product reliability. Today, many customers and designers are no longer content with the knowledge that production welds made by the same procedure will have similar mechanical properties. They want to know for certain that the welds used in their products are completely satisfactory and free from cracks, porosity, slag inclusions and other flaws. And the only way to determine the soundness of production welds is by nondestructive testing.

In the manufacture of missiles, for example, reliability is extremely important because a large number of parts must perform simultaneously in a satisfactory manner. But because the design of missile parts is severely limited by weight considerations, every vital part must be designed with a minimum factor of safety. Ordinary quality control methods in this kind of situation are not enough.

In this day of complex critical processes such as atomic power, the possibility of failure in one part may result in the costly failure of others. Another area for concern is insurance against disastrous failure in products such as transportation equipment that might cause loss of life.

These are sufficient reasons for a welding engineer to be well informed on nondestructive testing

GLENN J. GIBSON is Senior Welding Engineer, Carpenter Steel Co., Reading, Pa.

Fig. 2—Electronic measuring equipment automatically rejects bars that are subpar in surface quality

Fig. 3—Reflectascope used at Carpenter Steel Co. to inspect welds. This ultrasonic testing machine transmits high frequency sound waves through weld; cracks, blow holes or slag inclusions disrupt wave pattern and are easily detected on oscilloscope

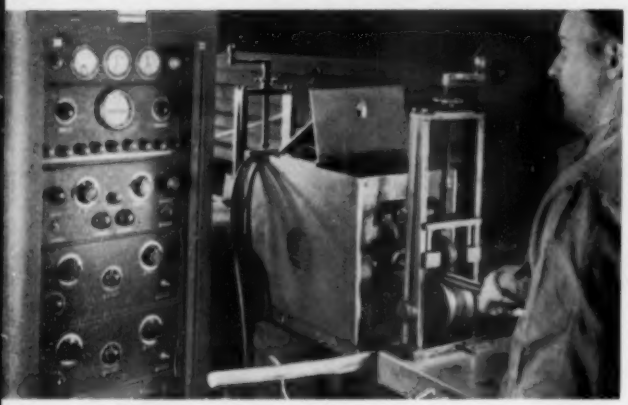


Fig. 4—Magnetic testing equipment can be used to assure surface soundness of steels

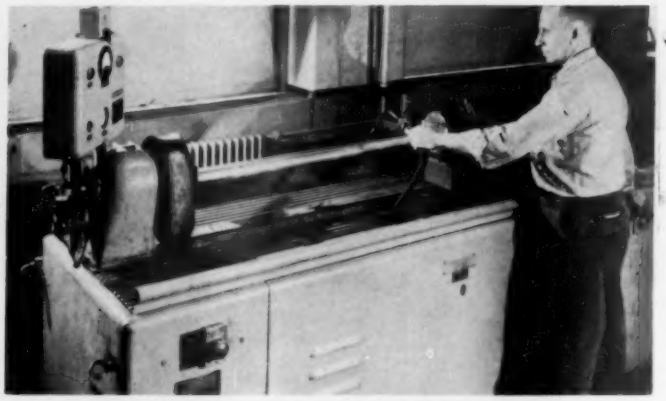


Fig. 5—Current of electricity in this nondestructive testing machine probes surface and subsurface of steel bars to assure soundness

methods and to keep abreast of new developments.

There are also cost advantages to consider. A manufacturer may regard new testing methods required in specifications of his product as another hazard in making a profit. However, it often happens that the initial experience with a new nondestructive testing method is found better than the method previously used.

All nondestructive testing methods other than visual inspection require a probing medium to indicate the soundness of the weld material beyond the visual surface. These probing media can be classified into two categories—motion of matter and the transmission of energy. There are some methods which employ a combination of these two.

Motion of Matter Tests

Generally, nondestructive testing methods employing the motion of matter require the defect coming to the surface.

Leak testing was one of the first nondestructive methods used on welded products. There are several types of leak tests which involve the motion of water, air or helium passing through a defective weld seam.

Where a highly competitive, relatively inexpensive product is involved the simplest way of leak testing is to put 3 or 4 lb of air pressure inside the container and swab outside seams with soap bubble solution.

Another form of leak test employs high pressure air in tubing or pipe submerged in water to indicate leaks.

The next step in upgrading of leak tests is what is called a proof test. This is a hydraulic test where the pipe or container is filled with water and pressure is applied so that the stress in the container is at or close to yield stress point of the material and can result in fractures of defective welds.

Probably the most sensitive of all leak tests is the helium mass spectrometer test. Helium can pass through crevices which are too small for air or water to permeate. Minute traces of helium leakage are detectable by the mass spectrometer test. This test is frequently used in complicated heat exchanger and pressure vessel testing. It can be applied to a vacuum system as well as a pressure system in a number of different ways.

Another matter-in-motion test is the liquid penetrant test. In its original form this test—known as the machine shop oil and whiting test—is as old as the metal industry.

The surface to be inspected is covered with an oil

or dye which penetrates into any invisible cracks or seams. The surface is then wiped off so that no visible trace of the oil or dye remains. Then the area is coated with an opaque, chalky liquid. When dry, the opaque coating acts as a blotter to draw out the penetrant from any cracks that might be present.

This method is very effective for showing any crack of practically any magnitude which comes to the surface of the material or weld.

Transmission of Energy Tests

Nondestructive testing methods employing the transmission of energy can locate defects entirely within the interior of the weld.

The oldest of the probing methods using transmission of energy is radiography. The source of radiant energy is either an X-ray tube or a radioactive isotope such as cobalt 60. Maximum capacity of X-ray radiography is generally considered to be 16 in. of steel for the highest voltage machines. For checking welds, however, X-ray machines of from 100 to 400 kv are used for steel up to 4 in. thick. The maximum thickness of steel that can be radiographed with a cobalt 60 source is about $7^1/_2$ in. regardless of the size of the capsule.

Ultrasonics. The ultrasonic method generally used for weld inspection is the pulse echo system. In this equipment, sound waves above 250 kc are generated in a crystal from a high frequency electrical generator. The crystal, enclosed in plastic, can be moved by hand along the welded seam. When the pulse encounters a flaw within the weld it sends back an echo which is in turn picked up by the crystal and indicated on a cathode ray tube as a peak or blip. As the search crystal is moved back and forth along the weld seam, an entire weld section can be scanned for flaws.

There is practically no limitation on the maximum thickness of materials that can be examined by this method. There are many ways of applying the pulse echo system to various shapes and types of welds.

Eddy Current Testing. This is a relatively new method of nondestructive testing which employs the principle of transmission of energy. Its major use today is in the inspection of thin-walled tubing.

In operation, electrical currents are introduced by electromagnetic induction. Whenever an a-c coil is brought in proximity to a conductive material eddy currents are induced in the object. These eddy currents produce a magnetic field of their own which affects the general impedance of the coil.

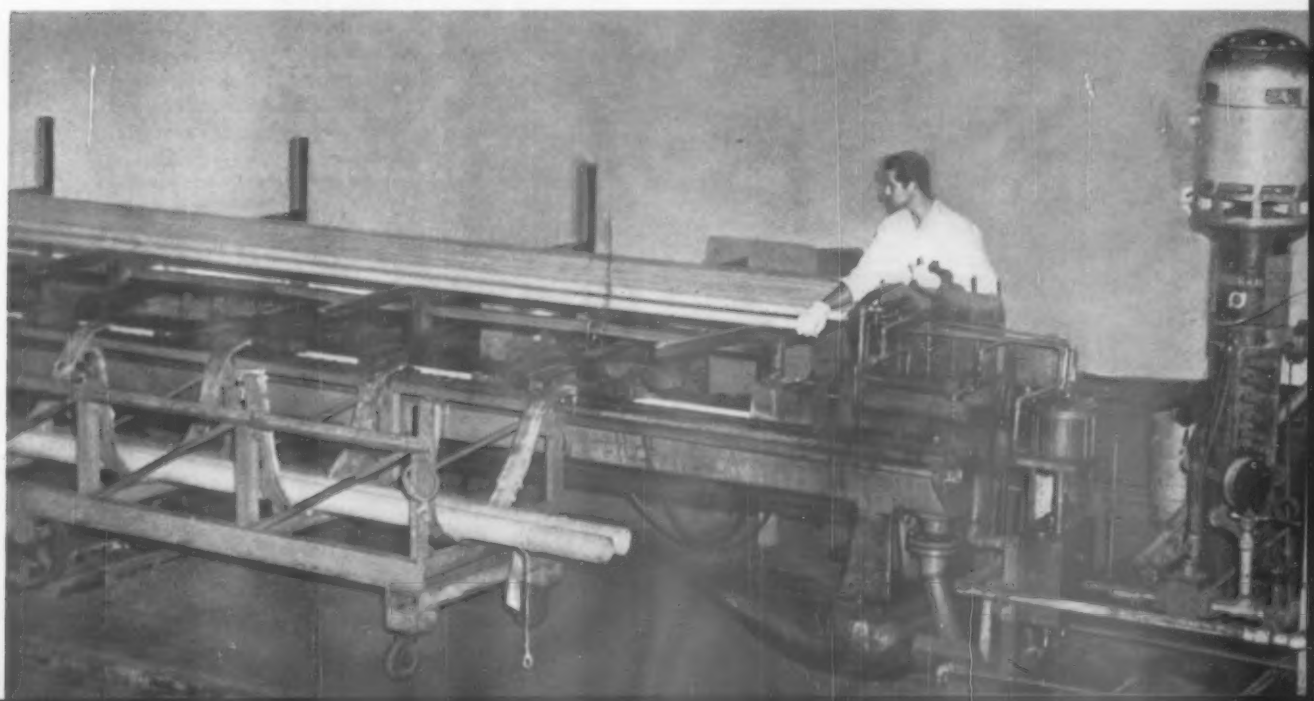
In a typical eddy current testing setup, thin-walled tubing is passed through a stationary coil at a speed of about 200 fpm. There is no electrical contact between the tube and the coil. Defects in the wall of the tube or the seam weld affect the flow of the eddy currents which, in turn, change the impedance of the coil. These changes can be registered in the form of blinking lights, ringing bells or be used to actuate a paint brush to mark the tube at the defective point.

Magnetic Particle Inspection Method

The magnetic particle inspection method, used widely in industry during the past 30 years, uses both the principle of matter in motion and the principle of transmission of energy. It is applicable only to testing of magnetic materials.

The method requires that the piece be magnetized, which usually is accomplished by passing a large current through the part by wrapping a coil around the section. Any defects or flaws at or near the surface of the part create magnetic leakage fields. These leakage fields attract magnetic particles which

Fig. 6—Hydrostatic testing machine checks strength and soundness of welded stainless steel tubing and pipe; water is applied inside the tubing at pressure up to 20,000 psi fiber stress



are applied to the surface of the part, indicating the extent of the defect.

Magnetic particle inspection has been found very sensitive for locating surface cracks, but its ability to locate cracks and defects beneath the surface is difficult to define.

Inspecting Welded Joints

First, consider resistance welding of which spot and seam welding are the most common types.

In spot welding there is the lap type seam with an intermittent type joint. The weld nugget is completely closed in the overlapping sheets, and there is no nondestructive testing method which is 100% reliable in testing spot welds. The only industry that does much nondestructive testing of spot welds is the aircraft industry in joints in aluminum sheets. The method used is usually X-ray radiography and the criterion of soundness is simply similarity in pattern of the spot welds. In seam welding, the same system applies.

Flash-butt resistance welding is widely used to join bar stock. The most common application is for making rings. After the flash is removed practically all of the nondestructive testing methods can be used to inspect resistance butt welds. The choice depends on which method is best suited to the geometry of the weld.

Resistance butt seam welding is used to a large extent in the manufacture of carbon steel pipe and tubing. The most popular nondestructive testing methods for this type of product are the leak tests, but the ultrasonic method can be used effectively. In one recent application, an ultrasonic crystal was mounted on the tubing as it passed through the tube mill so that a continuous quality control on the weld was indicated. Eddy current testing is also another possibility for welded steel tube inspection.

Fig. 7—Final inspection of welded stainless steel tubing and pipe is done on an electronic device which checks outside and inside surfaces, wall thickness, subsurface condition and verifies chemicals analysis—all at production speeds

Most of the nondestructive testing quality control methods are used on fusion welded butt joints. One important factor which influences the choice of the testing method is the accessibility of the welded joint. The ultrasonic test method is probably the only method in which complete testing can be done from only one side.

For fillet welds, nondestructive testing methods are difficult to apply for anything other than surface cracks. Complete root penetration is an important quality factor in fillet welds—a tough assignment for nondestructive testing. Varying degrees of thickness which are characteristic of fillet welds make radiographic testing difficult to interpret. Ultrasonics is another possible method, but again the interpretation is difficult.

One of the big fields of application for nondestructive testing has been in the inspection of pipe joints. Included are oil and gas transmission pipe as well as the piping in steam and power plants and atomic power installations. The method generally used in field inspection of transmission pipe is to suspend an isotope source at the center of the location of the weld seam. The radiographic film is then wrapped around the seam. This gives a complete exposure at one time.

There are also special types of X-ray sources that give a 360 deg field of radiation for this type of application. Since the critical part of any pipe welding job is the root pass, this quite often is inspected before the remainder of the weld is completed. Frequently, this is accomplished by the liquid penetrant method on the outside of the pipe.

Conclusion

Any nondestructive testing method can be used either to scan the whole product or samples representing production. Whenever it is used for quality control it should be applied as close to the operation responsible for the defect as possible.

The most difficult problem in any nondestructive testing application is establishing quality levels. It should be understood that total perfection is not a realistic goal. Some deviation from perfection must be tolerated. This is why there are tolerances and differences of opinion between producer and user.

The big potential in nondestructive testing is its ability to help industry approach perfection by narrowing the gap in tolerances.

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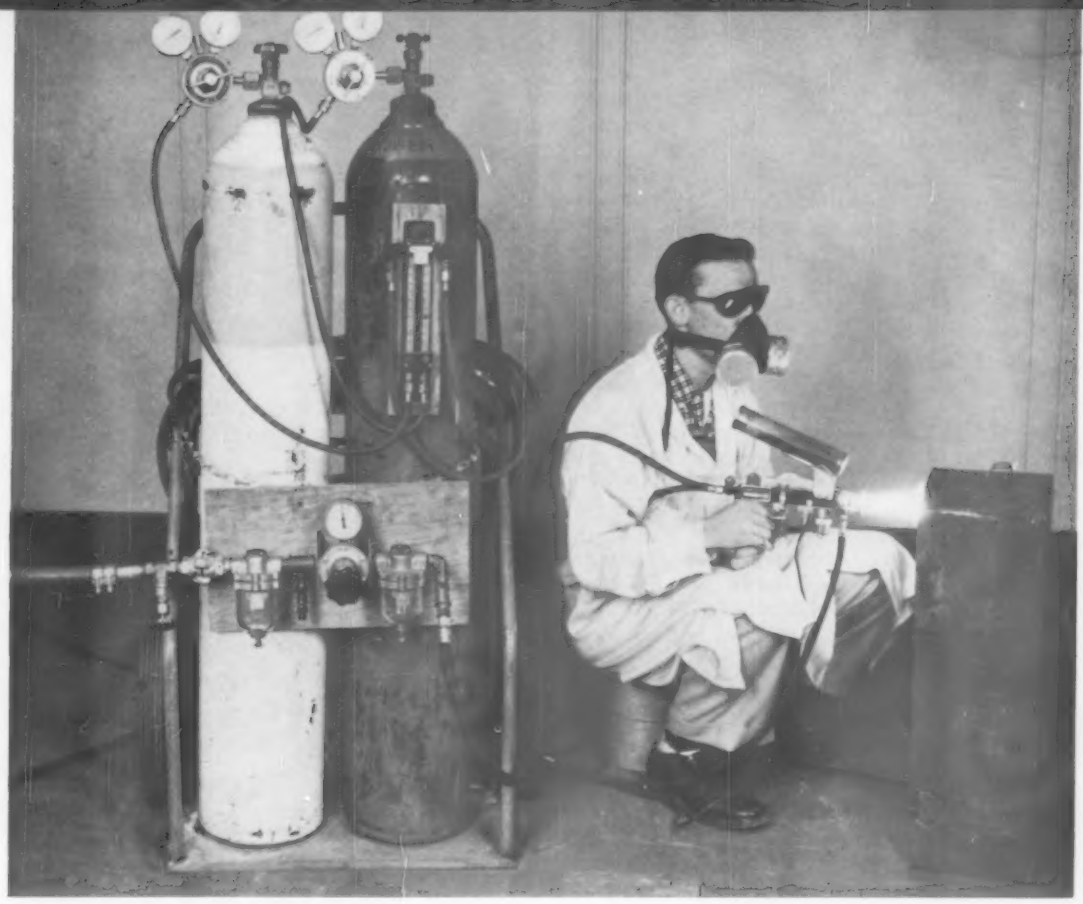

Operator using apparatus for spraying nickel powder

Metallizing Nickel Powder

involves vacuum blasting to prepare steel before surfacing with metal-spray gun

BY W. B. KEYSER

SUMMARY. A program was established under Contract AT-(33-2)-1 with the United States Atomic Energy Commission to study the feasibility of applying a corrosion-resistant coating to bare steel by metallizing nickel powder. Both the technique for preparing the base surfaces prior to metallizing and the metallizing techniques for applying a nickel coating were investigated.

It was determined that a vacuum-blast machine serves as a suitable portable apparatus for preparing a metal surface for spraying, while a metal-spray gun accomplished satisfactory spraying of nickel powder.

Introduction

The suitability of nickel-plated steel for use in various industrial chemical processes has been well established. During maintenance and modification of process equipment, nickel plating is often removed and the exposed metal surfaces became susceptible to chemical attack. A program was initiated to study the feasibility of applying a corrosion-resistant nickel coating by the metallizing techniques.[1-3] Metallizing or the application of a metal coating to a surface by spraying the surface with molten metal has two advantages. They are:

1. The portability of the equipment makes the process applicable to reclamation of materials in isolated areas.

2. Metallizing makes possible the application of a nickel coating over a mild steel weld that joins two nickel-plated pieces, thus saving the expense of nickel welding filler wire.

W. B. KEYSER is associated with the Goodyear Atomic Corp., Portsmouth, Ohio.

Experimental Work and Results

Surface Preparation

One of the most important requirements in protective coating technology is proper preparation of the surface to which the coating is to be applied.

Since it would not be practicable to heat the sprayed metal and the base metal in order to fuse the two materials, the base metal must be prepared to mechanically bond with the nickel being applied. Most sprayed metal particles, which strike the surface, are sufficiently plastic to conform to the irregularities and identations of the surface and thus mechanically interlock with them.

A vacuum-blast machine shown in Fig. 1 was purchased for evaluating different surface blasting techniques. The prime advantage of the machine was that it is portable. It provides a means for blasting almost anywhere without interfering with associated maintenance. The subject surface is blasted beneath two concentric nozzles which are surrounded by a brush. Abrasive is directed through the inner nozzle. The instant the abrasive has done its work, the outer vacuum pick-up nozzle returns it, together with the debris, to a reclaimer. Only compressed air is needed to operate the machine.

Initial blasting tests revealed that the use of aluminum oxide and silica sand in the machine was undesirable. These two nonmetallic materials fractured easily and embedded themselves in the surface of the metal. The embedded particles reduced the adherence of the sprayed coating.

Several metallic grit sizes were tested. It was determined that, for both optimum operational efficiency of the machine and maximum roughness of mild steel surfaces, SAE size G-25 crushed chilled iron blasting grit was the best. The use of larger grit resulted in malfunctions of the machine; smaller grits did not roughen the steel surface sufficiently. New, clean grit was used and precautions were taken to maintain the sharpness of the abrasive. Air pressure at 90 psi was necessary for the maximum efficiency of the machine.

It should be noted that oil and water in the blast, as well as worn nozzles and dirty or rusty grit, greatly reduce the bond strength of the sprayed coating.

Metallizing

Until recently, most sprayed metal coatings were applied by feeding a wire into an oxyacetylene flame where it was melted. An air blast then blew the molten metal particles onto the surface being treated. This type of coating was porous as shown in Fig. 2, and its use for resistance to corrosion was limited. Recent commercial developments have made available a special metal powder spray gun, which was purchased for evaluating sprayed nickel as a prospective protective coating for bare steel.

Since the commercial development of the method of spraying nickel powder has not been accomplished, nickel powder was acquired for testing. Spectrochemical analyses showed that the powder had the following composition: nickel—99.05%; silicon—0.029%; molybdenum — 0.02%; aluminum—0.003%; carbon — 0.09%; sulfur — 0.006%; boron — 0.05%; copper — 0.09%; chromium—

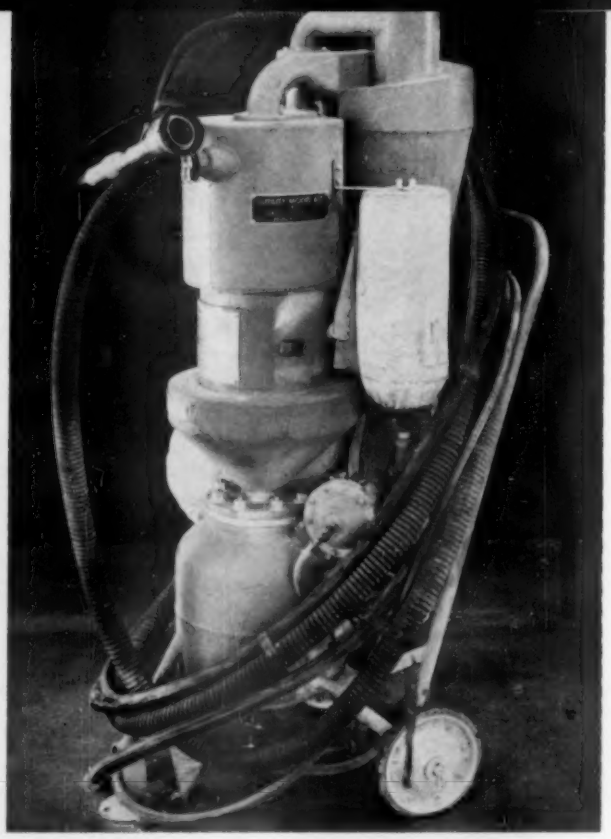

Fig. 1—Vacuum-blasting machine

0.05%; magnesium — 0.02%; and manganese—0.03%. The average particle size was determined to be 3.85μ. This powder was used for spraying all samples.

The powder gun was designed to spray several different materials. Tests were conducted to determine the conditions which yielded the nickel coating of greatest density. These tests revealed that for optimum results the following operating conditions should be established when using the gun and appropriate flowmeter:

1. Hydrogen flow—40 cfh
2. Oxygen flow—20 cfh
3. Flow control valve—13 clicks
4. Metering valve—No. 5
5. Air cooling pressure—50 psi.

A ceramic nozzle and vibrator should be used. Furthermore, the gun should be held with the nozzle approximately 4 in. from the work as illustrated in the lead photograph which depicts the apparatus used by an operator for spraying nickel powder.

The greater density of the sprayed powder, as compared to the sprayed wire, can be seen by examining Figs. 2, 3 and 4. X-ray diffraction analysis of the coating shown in Fig. 3 indicated that it contains approximately 40% metallic nickel, 40% nickel oxide and a total of 10% β- and γ-nickel hydroxides.

Sprayed metal coatings contract after application. Contraction, in turn, results in the formation of stresses within the coating which may affect the

mechanical bond between the coating and the base. As the thickness of the sprayed metal increases, the contracting stresses increase to values greater than the adhesion forces, and cracking of the coating results. Concave and flat surfaces present greater problems, with regard to shrinkage of the coating, than do convex surfaces. Coatings on concave surfaces tend to shrink in a direction which would loosen them. Accordingly, tests were conducted to study the bond strength, using the described surface preparation method, for flat mild steel samples and for concave samples with inside radii no less than 5.5 ft. It was determined that there is a maximum, as well as a minimum, overlay thickness. A layer at least 0.020 in., but not more than 0.050 in., thick on flat or slightly concave surfaces should be applied.

A cross section was cut from test samples for bend tests. The size of the bend samples was $^3/_8$ x $^3/_8$ x 2 in. The sprayed plating started to peel on each of the samples after bending of about 5 deg. The bend tests revealed the relatively low bonding tensile strength of the sprayed nickel powder coating.

Conclusions

Observations made during the course of the work herein described indicate that metallized nickel powder is applicable for service in industrial chemical processes. Like most specialized metallurgical materials, however, it has its limitations. The application of metallized nickel powder to chemical process equipment requires close control of all phases of the process to insure optimum results.

The prominent steps necessary for nickel powder metallizing are as follows:

1. Degrease.
2. Preheat area to 300–400° F. (This eliminates the condensation of water from the burning of hydrogen and oxygen; the condensation causes formation of rust, which reduces the bond strength.)
3. Vacuum blast.
4. Metallize.
5. Clean with wire brush.

The advantages of metallized nickel are twofold. First, the equipment is portable, which makes possible the renovation of process equipment. Second, the coating does protect mild steel from corrosion by chemical agents.

Metallized nickel has three disadvantages. In the first place, the coating will peel if it is too thick or if the surface is not properly prepared. Furthermore, the coating will not offer corrosion resistance if it is too thin, and—finally—the coating has low tensile and bond strength.

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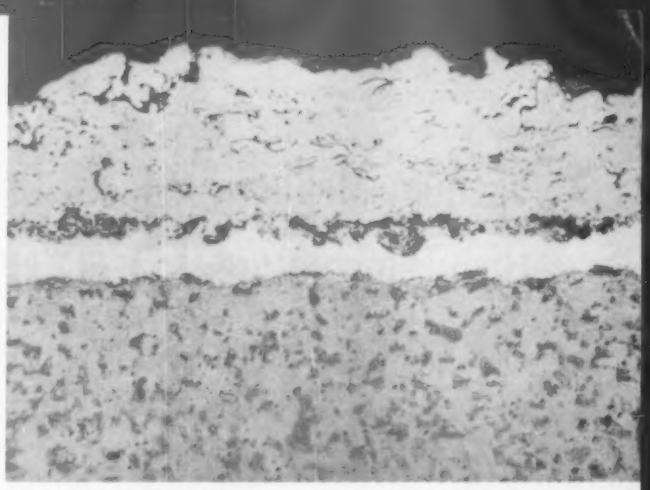


Fig. 2—Photomicrograph of cross section of metallized nickel wire on electrolytically nickel-plated steel with porosity to be noted in the metallized nickel wire coating. Etchant: 2% Nital; × 100

Fig. 3—Photomicrograph of cross section of nickel powder metallized with oxyhydrogen torch. No etchant; × 1000

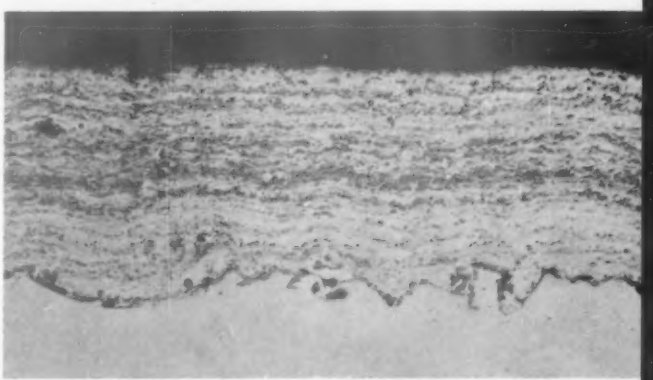


Fig. 4—Photomicrograph of cross section of metallized nickel powder. No etchant; × 100

Vacuum Melting Produces Cleaner, Better Performing High-Temperature **Brazing Alloys**

which are suitable for use with 0.001–0.005-in. core materials in honeycomb brazing as well as bridging up to 0.060-in. joint clearances

BY C. R. BENSON

Extreme penalties exacted by excess weight in jet engine, airframe and missile structures has resulted in an almost universal trend toward light sheet metal assemblies joined by brazing. With this trend has come a demand for better, more dependable high-temperature brazing alloys—a demand met by vacuum melting.

Besides elimination of excess weight there are other reasons for the brazed assembly. Some components are too complex or too costly to make in any other way. In other instances brazing eliminates or minimizes distortion, strain-age cracking, stress relieving and other problems associated with the welding of precipitation-hardening of high-temperature super alloys.

The critical nature of air- and space-born structures requires rigid quality control of materials and of manufacturing procedures. While this is established routine for the materials from which the parts have been made, it has not been true of the high-temperature brazing alloys. Due to circumstance rather than choice, about the only requirement that has been placed on the brazing alloys was that they meet the specified chemistry and melt at the required temperature.

Brazing alloys usually are manufactured in powder form. Powders cannot be inspected by micro-examination, zyglo, magnaflux and ultrasonic techniques used for the base materials. Consequently, the only effective quality control is the method by which the powders are melted and processed. By its inherent advantages vacuum melting produces a cleaner, higher-quality product that is essentially free of undesirable oxides and impurities.

Background of Brazing Alloys Production

Vacuum melting, then, is a major advancement in improving the quality and cleanness of metals, particularly high-temperature brazing alloys. Since the inception of high-temperature brazing about 12 years ago, the alloys have been melted in air or under a partially protective atmosphere. The powder form generally was achieved by water atomization of a molten metal stream or by ball milling, crushing, filing, pulverizing, etc., of a cast shape.

Most high-temperature brazing alloys consist of nickel-base material alloyed with chromium, silicon and boron. Melting in air or under a partially pro-

C. R. BENSON formerly with the Metallurgical Products Dept., General Electric Co., is now associated with Wyman-Gordon Co., Worcester, Mass.

Enlarged view of honeycomb seal shown in Fig. 4

tective atmosphere usually results in formation of undesirable oxides and other impurities. In the atomization process, the material is subjected to additional oxidation and contamination by the water. To reduce the oxides, the powders are cycled through a hydrogen treatment at a temperature considerably below the solidus of the alloy.

This does not reduce many of the oxides, as is shown by examining the metal-metal oxide equilibria in hydrogen atmospheres as a function of dew point and temperature, reported by W. H. Chang[1] and reproduced in Fig. 1. Each curve represents a boundary separating the zone of oxidation (left-hand side) from the zone of reduction (right-hand side).

From these curves, it is evident that at a good commercial hydrogen dew point of −80° F, a temperature in excess of 1300° F is required to reduce the oxides of chromium and silicon which are intentionally added to the alloy, and manganese and aluminum which normally appear as trace elements. In fact, a temperature well in excess of 1700° F is required to reduce the oxides of chromium, manganese and aluminum. This latter temperature approaches the solidus of most braze alloys. Although these relationships were determined for pure metals, they are generally useful for metallic elements in alloys even though it is known that changes in equilibrium conditions occur.

Why Vacuum Melt?

Vacuum melting produces a cleaner alloy essentially free from the inclusions, undesirable impurities, oxides and absorbed gases common to air melted material. Removing the normal air atmosphere prevents undesirable reactions with oxygen and nitrogen while the heat is being processed. Volatile impurities such as lead, bismuth, cadmium and calcium readily vaporize and condense out of the system preventing further reaction. Biatomic gases are removed leading to lower absorbed gas contents by as much as four to one. Composition control is closer and alloys containing strong oxide formers can be produced by vacuum melting since substantial loss of essential alloying and reactive elements is prevented.

The basic improvements attainable by vacuum melting generally apply regardless of the alloys system. Cleaner alloys result in more uniform and consistent performance.

Vacuum Melting Process Improves Cleanness

Vacuum-melted brazing alloy powders are produced from high-quality rigidly controlled raw materials. The basic charge is melted in and processed under vacuum at pressures of from 1 to 10μ. Additions of reactive elements are made toward the end of the heat when the total absorbed gas and oxygen content has been reduced to the desired minimum.

The vacuum cast product consists of coarse, irregularly-shaped particles and platelets which are pulverized to −200 mesh powder. Pulverizing is accomplished in a hammer mill with a protective atmosphere flowing through the pulverizing chamber to minimize surface oxidation. Improved cleanness of vacuum melted alloys is shown in Fig. 2.

Surface oxides, which are common to air-melted powders, must be reduced during the brazing cycle, and—as shown in Fig. 1—the degree to which this is accomplished will depend upon the dew point of the hydrogen, the temperature and the degree of contamination of the powder. Since these are all variables, particularly the degree of contamination which can vary within and between different heats of the same alloy, the brazing results and temperatures can be affected significantly.

Previous investigations[2] have shown that the most satisfactory joints in the nickel-chrome-silicon and nickel-chrome-silicon-boron alloys are produced when zero clearance is maintained. If a zero clearance is maintained in a brazed joint and the brazing powders contain oxides or other impurities, they can become entrapped in the tight capillary preventing further flow of the brazing alloy resulting in voids in the brazed joint.

The importance of cleanness cannot be overemphasized, particularly when brazing high-strength lightweight structural components which will be used for critical applications. These fabricated parts are normally made of expensive materials that have been rigidly controlled for quality. By the time they are ready to be brazed, usually they are quite valuable due to previous fabrication costs.

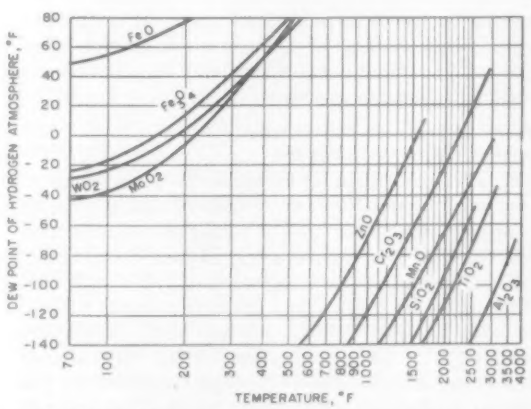
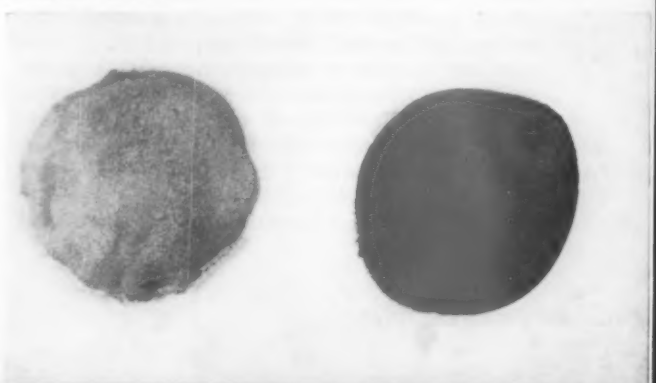
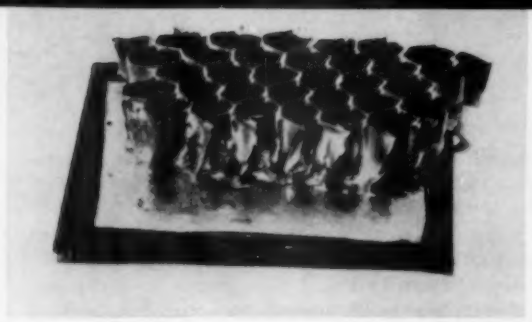


Fig. 1—Metal-oxide equilibria in hydrogen atmospheres[1]

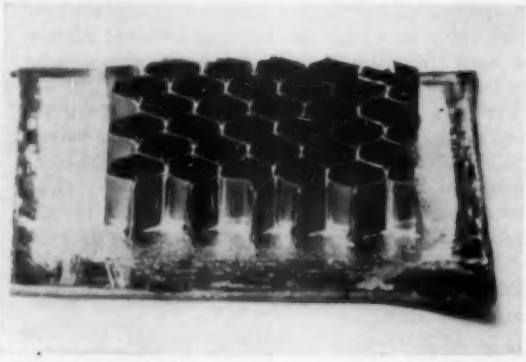
Fig. 2—Vacuum melting produces cleaner brazing alloys (left—vacuum melted Ni-Cr-Si; right—air melted Ni-Cr-Si)



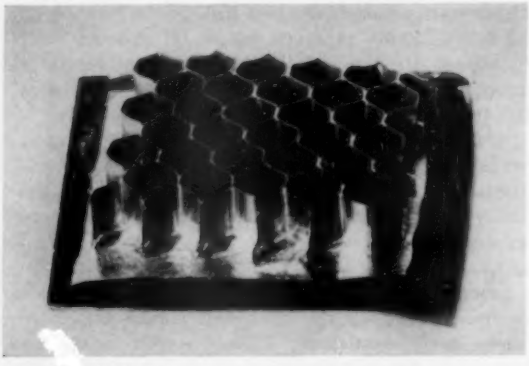


Air-melted Ni-Cr-Si

Air-melted J-8102



Vacuum melted Ni-Cr-Si



Vacuum melted J-8102

Fig. 3—Improved erosion characteristics of a vacuum melted Ni-Cr-Si brazing alloy and a heterogeneous brazing alloy (J-8102) consisting of two dissimilar powders (brazing temp.—2150° F; time at temp.—30 min.; honeycomb material—0.003-in. Type 304 stainless steel)

Since only a small amount of braze powder is required to form a joint, the more consistent results attainable with vacuum melted alloys more than compensate for the slight additional cost. It is difficult to justify the savings of a few cents in brazing alloy costs when joining parts which may be worth hundreds or thousands of dollars.

Lower Gas Contents—Particularly Beneficial for Vacuum Brazing

Huschke and Hoppin[3] reported the gas content of a vacuum melted Ni-Cr-Si (J-8100) brazing alloy to be appreciably lower over a range of temperatures than that of the identical air melted composition (GE-81). Their data is reproduced in Table 2. In addition to Huschke's and Hoppin's data, results[4] are also included for air melted Ni-Cr-Si-B alloy (AMS-4777). An examination of the data shows that vacuum melting has effectively reduced the gas content of the air melted Ni-Cr-Si alloy by a factor of approximately four to one. Reduction in oxygen content was proportional to the total.

In vacuum melting, undesirable impurities in the metal are effectively reduced and the gas content lowered by utilizing a carbon boil. The carbon reaction produces CO as an end product which is continuously removed by the pumping system. Because the vacuum is dynamic rather that static, reactions can be driven more nearly to completion since the reaction products are gaseous. This results in a continuous reduction of undesirable impurities and a lowering of the absorbed gas content. As the same principle applies, regardless of the metal being melted, the gas content of any vacuum melted braze alloy should be reduced by approximately the same factor of four to one.

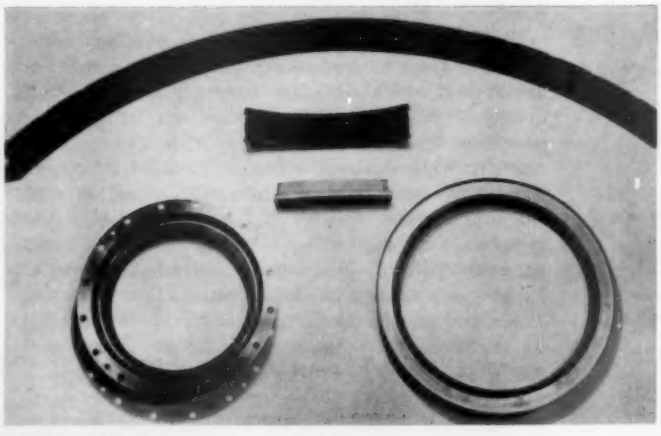


Fig. 4—Typical honeycomb parts as brazed with vacuum-melted alloys

The lower gas content of vacuum melted brazing alloys is particularly desirable in vacuum brazing. Significant pressure increases could be experienced with air melted alloys in vacuum, particularly when the brazing temperature is reached. The sudden outgassing could result in appreciable pressure increases as well as formation of surface oxides. This is particularly true on base materials containing appreciable quantities of aluminum and/or titanium. In their paper of vacuum brazing, Huschke and Hoppin[3]

Table 1—Nominal Composition of Typical Brazing Alloys

Alloy	C	Si	B	Cr	Mn	Ni
Ni-Cr-Si[a]	0.06 max.	10	...	19	..	Bal.
Ni-Cr-Si-Mn[b]	0.06 max.	10	...	19	10	Bal.
AMS-4755	0.10	4	3.75	17	..	Bal.
J-8102[c]	...	8.0	...	15.2	..	Bal.
J-8103[c]	...	9.2	0.08	17.1	..	Bal.
J-8104[c]	...	6.8	0.3	11.4	..	Bal.

[a] J-8100 vacuum melted designation.
[b] J-8300 vacuum melted designation.
[c] These alloys are mechanical blends of heterogeneous powders. Composition is that of the blended alloy.

Table 2—Outgassing of Vacuum Melted vs Air Melted Brazing Alloys[3,4]

Total outgassing in liters/gram at constant pressure (1-μ)

Material	1510° F	1800° F	2010° F	2100° F	2200° F
Ni-Cr-Si (air melted)	121	248	403	549	802
Ni-Cr-Si (vacuum melted)	83	88	117	152	206
AMS-4775 (air melted)	195	373	489	586	765

Gas by weight given off by each sample, %

Material	Temp., ° F	N_2	O_2	H_2
Ni-Cr-Si (air melted)	1800	0.0087	0.0129	0.0004
	2200	0.0225	0.0492	0.0009
Ni-Cr-Si (vacuum melted)	1800	0.0031	0.0012	0.0002
	2200	0.0050	0.0124	0.0003
AMS 4775 (air melted)	1800	0.0196	0.0183	0.0003
	2200	0.0178	0.0493	0.0008

observed a flow of $1^1/_2$ in. with a vacuum melted Ni-Cr-Si alloy as compared to $^1/_2$ in. with the similar air melted material on "tee" samples of A-286 vacuum brazed 20μ.

Improved Erosion Characteristics

Erosion by the brazing alloy is of prime consideration when selecting a material for joining the thin, lightweight sheet metal and honeycomb structures used in jet engine, air frame and missile applications. Vacuum melting decreases the erosion characteristics of the brazing alloy as shown in Fig. 2.

Other Advantages or Benefits and Improvements

In vacuum melting closer chemistry control can be maintained by preventing any substantial loss of essential alloying elements either through oxidation or undesirable reactions. Closer composition control and the improved cleanness, result in more uniform brazing temperatures and more consistent performance.

New Alloy

The ability to produce clean materials containing reactive elements was instrumental in the development of a Ni-Cr-Si-Mn alloy, a manganese modification of the Ni-Cr-Si alloy. The manganese lowers the 2125–2175° F brazing temperature of the Ni-Cr-Si alloy by 50–100° F, resulting in a very low erosion characteristic.

The high manganese content (10%) precludes the use of conventional air melting. Attempts to produce satisfactory material by air melting and atomizing were unsuccessful because of severe oxide contamination.

Applications

Vacuum melted high-temperature brazing alloys are recommended for universal specification on military and commercial applications where uniform and consistent performance is necessary. The vacuum melted Ni-Cr-Si alloy, because of its more reliable performance, is in widespread use on military and nuclear applications replacing the air melted composition.

Open face and completely enclosed honeycomb structures are being brazed with the Ni-Cr-Si-Mn alloy and a vacuum melted, mechanically blended heterogeneous alloy (J-8102) of two dissimilar powders. Hastelloy X, Inconel X and stainless steel types 410, 321 and 347 core material ranging in thicknesses from 0.0015 to 0.015 in. are being successfully brazed to A-286, Inconel W, Inconel, Hastelloy and stainless steel types 410, 321 and 347 backup and facing material—Table 3. Typical metal honeycomb parts brazed with vacuum melted alloys are shown in Fig. 4 and in the lead photograph.

The turbine nozzle assembly shown in Fig. 5 is fabricated and brazed using a number of operations and vaccuum melted brazing alloys. The trailing edge of the vane is brazed with a heterogeneous mechanically blended alloy (J-8103) which has a very low erosion characteristic. Simultaneously, an internal core is brazed to the vane using the Ni-Cr-Si alloy. Finally, the turbine nozzle assembly is completed by brazing the vane sections to the inner and outer bands using another heterogeneous mixture (J-8105) which is capable of bridging up to 0.060 in. gaps.

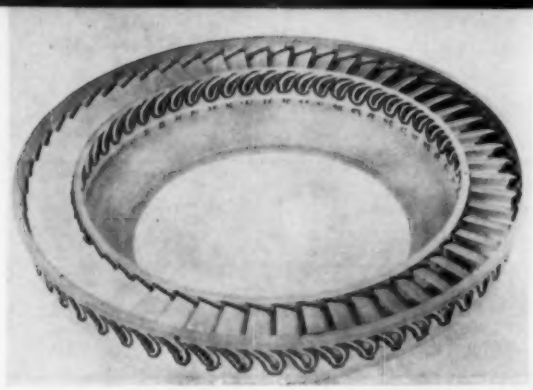


Fig. 5—J-79 turbine nozzle assembly after brazing cycle

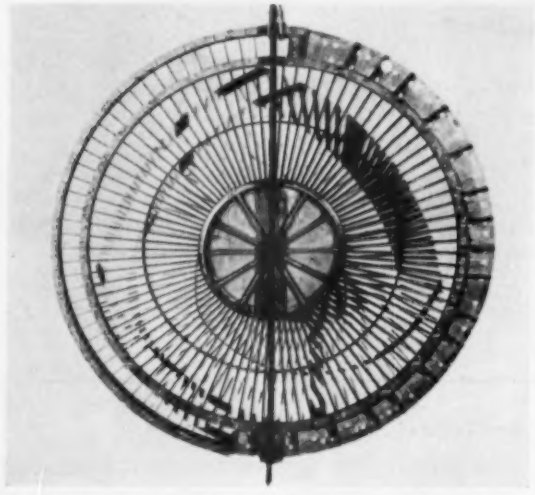


Fig. 6—Fan rear frame brazed with vacuum melted alloys; fabricated from 0.020-in. thick sheet—more than 700 joints brazed simultaneously

The fan rear frame shown in Fig. 6 was hydrogen brazed at 2130° F and rebrazed at 2050° F with vacuum melted brazing alloys. The fan is 75 in. in diam and was fabricated of 0.020 in. thick Inconel X sheet. Over 700 joints were brazed simultaneously.

Availability

Vacuum melted high-temperature brazing alloys are commercially available and can be classified according to their characteristics and applications. They are (1) general purpose alloys requiring the normal 0.001–0.003 in. joint clearances for applications where conventional air melted materials are used, (2) honeycomb alloys for the high-temperature brazing of thin 0.001–0.005-in. core material, and (3) wide gap brazing alloys for the bridging of up to 0.060 in. joint clearances. Figures 7 and 8 show a typical braze with the wide gap alloy.

Summary

Vacuum melting produces cleaner brazing alloy powders which are essentially free of inclusions, undesirable impurities, surface oxides and absorbed gases. Improvement in erosion characteristics are achievable as well as closer composition control and cleaner materials containing reactive elements.

The improved cleanness insures more uniform and consistent performance for vacuum or atmosphere brazing. The lower gas content of vacuum melted brazing powders is particularly desirable and advantageous for vacuum brazing. They are recommended for universal specification on military and commercial applications.

Table 3—Typical Honeycomb Parts Brazed with Vacuum Melted High-temperature Brazing Alloys

Description*	Back up material	Honeycomb material	Cell size	Honeycomb thickness
J-93 turbine shroud	Hastelloy X	Hatelloy X	0.062	0.010
J-93 seal	410 SS	321 SS	0.125	0.005
CJ-805 aft fan seal	321 SS	321 SS	0.035	0.002
J-93 bearing seal	Lapelloy	321 SS	0.062	0.005
J-93 seal	Hastelloy C	Inconel	0.125	0.005

* Top to bottom.

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4. Huschke, E. G., "A Quantitative Measurement of the High-Temperature Gas Evolution of Six Materials in Vacuum," General Electric Co., Flight Propulsion Division, Memorandum Report 57-FD-4, April 12, 1957.
5. Yelton, P. G., "Erosion and Flow Characteristics of Vacuum Melted vs Commercially Available GE-81 Brazing Alloy," General Electric Co., Flight Propulsion Division, Memorandum Report 57-FD-16, July, 19, 1957.

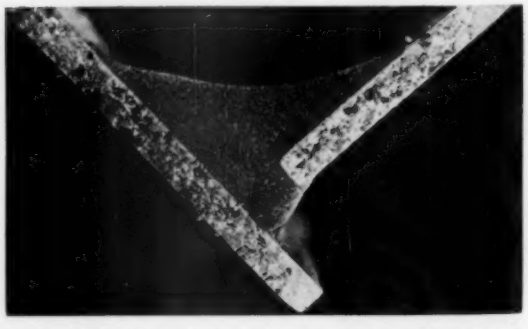
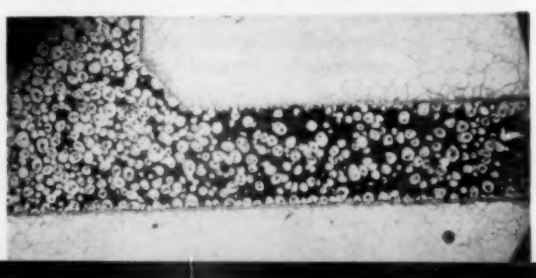


Fig. 7—Typical braze with wide gap alloy enlarged × 5. (This is a mixture of two powders—one high melting, the other low. The low melting point powder melts at brazing temperature, the high does not, but is wettable by the fluid. The two continue to fill the gap—the particles of the high melting point powder acting somewhat like the aggregates in concrete) Reduced approximately 50% on reproduction

Fig. 8—Microscopic section of wide gap braze—particles of high melting point powder show white



Field erection of 6,300,000-gal oil storage tank

Today's Industrial Role of **Magnetic-Flux** Gas-Shielded Arc Welding

is keynoted by increasing use and by process advances featuring a broader range of wires and improved fluxes

BY R. T. TELFORD

What is industry looking for in the welding of carbon steel? A partial answer would be to say that industry is constantly on the lookout for a mild-steel welding process that is capable of both reducing costs and increasing productivity. Covered-electrode welding has long been a reliable work horse for mild-steel fabricators. It has, however, been subject to several disadvantages—one example is the need to interrupt welding constantly to replace electrode stubs. Thus the trend has been to seek a continuously-fed welding wire process capable both of operating under the most adverse shop conditions and of producing welds comparable in quality to those produced with the covered-electrode process.

Magnetic-flux gas-shielded arc welding was introduced to industry in 1957.[1] Since then, it has been utilized in just about every segment of industry.

R. T. TELFORD is Project Engineer, Development Laboratory, Linde Co., Div. of Union Carbide Corp., Newark, N. J.

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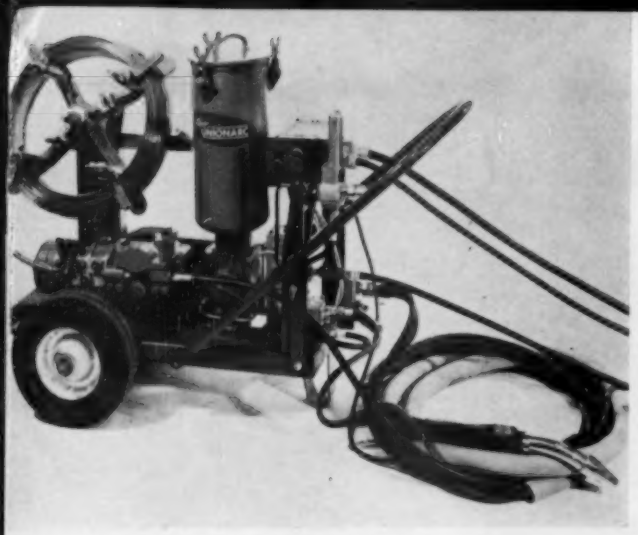

Fig. 1—Magnetic-flux gas-shielded arc welding machine with torch

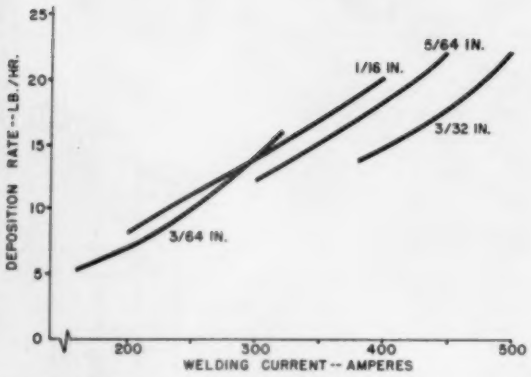

Fig. 2—Magnetic-flux welding wire deposition rates

It has been used on earth-moving equipment, field erected storage tanks and in small structural shops as well as in large tank shops. During this period, the process and its application have undergone continuous development. Furthermore, fabricators have gradually learned how to use the process to best advantage.

Recent improvements promise to make the magnetic-flux process even more effective. These include improvements in the equipment, a broader range of wires, and the development of improved fluxes.

Present Status

Equipment Requisites

The process employs a heavy-duty wire feeder to feed wire from 25- or 65-lb coils through the flexible conduit to the torch. The flux is stored in a hopper of about 25 lb capacity and is metered from the dispenser; "on and off" flow is controlled by a solenoid valve and an electromechanical pinch valve. Carbon dioxide gas conveys the flux through a rubber hose to the torch where it is attracted to the wire by the magnetic field established around the current-carrying welding wire.

A typical machine is illustrated in Fig. 1. This machine is equipped with a blowpipe-type torch and embodies improvements in wire feeding and flux dispensing to enable it to perform under the most rugged shop conditions. It can be easily moved to different locations. By comparison, early magnetic-flux welding machines utilized a 300-lb drum of wire. On applications where the equipment was fixed at one location, this arrangement proved advantageous. However, this equipment had its limitations for other applications where it was necessary either to move or to suspend the equipment in the shop.

To operate present equipment shown in Fig. 1, the operator sets the potentiometer on the machine to deliver the wire necessary to satisfy a given current condition. The flux ratio is set on the hopper. By merely touching a start button, an arc is established and the operator proceeds to make his weld.

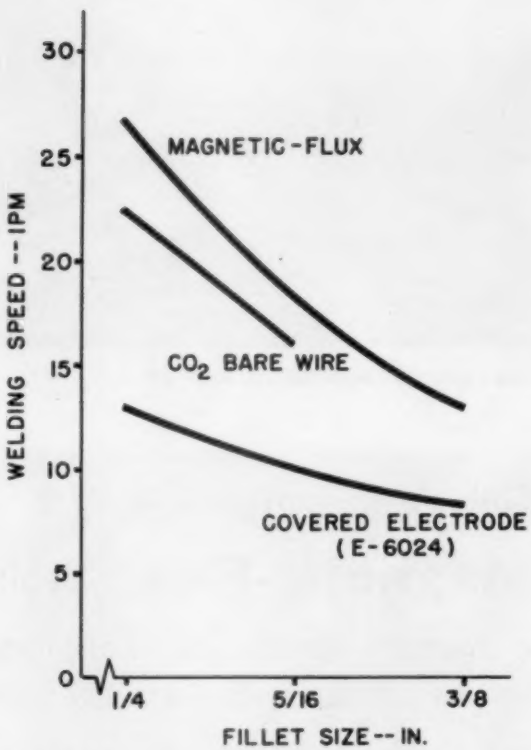

Fig. 3—Welding speeds for magnetic-flux, covered electrode and carbon-dioxide welding processes

Welding Wire Advances

When the magnetic-flux process was first introduced in 1957, welding wire was available in only two sizes—$^{3}/_{32}$ and $^{3}/_{64}$ in. diam. Each had its place and each performed satisfactorily except when poor fit-up was encountered or when currents in the range of 300 amp were required. Now $^{1}/_{16}$- and $^{5}/_{64}$-in. diam wires are available to fill this gap, thereby making the process more applicable to

Fig. 4—Penetration in horizontal fillet weld—left, magnetic flux; right, covered electrode

lighter gages and enabling the process to tolerate poor fit-up.

The significance of this advance is seen in Fig. 2, which illustrates the deposition rates obtained with different size wires at various currents. It is interesting to note that a small diameter wire will often deposit considerably more metal than larger wires at a given current. This can be used to advantage especially where large amounts of metal are required such as on casting repair work where $^{1}/_{16}$- or $^{5}/_{64}$-in. wires can be used to advantage in preference to the $^{3}/_{32}$-in. wire.

There are certain minimum thicknesses that can be welded with each wire size. Under practical field conditions, the minimum plate thickness, which can be handled, is approximately twice the wire diameter. The $^{2}/_{64}$-in. diam wire is used for welding in all positions whereas the other wires are generally restricted to down-hand welding.

Flux Developments

Early experience indicated the need for close control of flux formulation and mechanical properties in order to ensure a uniform product. Control procedures have been perfected and are now routine. Moreover, a new recently developed flux will reduce flux consumption, provide better visibility on many joints and broaden the scope of operating conditions over the whole process range. While the original fluxes could be used only with reverse-polarity direct current, the new fluxes can be used with straight-polarity direct current to advantage—especially in down-hand welding where it becomes possible to utilize the greater deposition rates experienced with this form of power. Thus the new flux offers several technical and economic advantages to the user.

Magnetic-flux Process Characteristics

Welding Speeds

Magnetic-flux welding speeds have been slightly increased ever since inception of the process. This is due principally to the use of the greater welding wire extensions with the torches of today. This together with the flux and techniques presently employed allows the production of good shaped welds at high welding speeds without undercutting. The increased wire extension causes a change in metal deposition on the order of 10% which, in turn, results in a 10% increase in welding speed as compared to that obtained with the process originally.

The significance of increased magnetic-flux welding speeds is illustrated in Fig. 3, which compares the welding speeds obtained with the magnetic-flux process as well as with both carbon-dioxide shielded and covered-electrode welding. In comparison to results obtained with E6024 electrodes, the magnetic-flux process is approximately twice as fast for preparing $^{1}/_{4}$- and $^{5}/_{16}$-in. size welds. On the $^{3}/_{8}$-in. size welds where high currents can be used on all such rods, the increased welding speed obtained with the magnetic-flux process is on the order of 60%. In comparison to carbon-dioxide welding, magnetic-flux welding is only about 15% faster but results in much better weld quality and undercutting is not a problem. Moreover it is much more applicable to producing a variety of weld sizes in the horizontal position.

The curves in Fig. 3 were plotted from data obtained by making many horizontal fillet welds in plate wherein the leg sizes of cross-sectioned welds were measured and then plotted vs. welding speeds for the various processes. In this series of tests, the E6024 iron powder electrode was selected since it is about the fastest of the covered electrodes now used by industry. The $^{3}/_{16}$-in. diam electrode was used on $^{1}/_{4}$-in. size welds, while a $^{1}/_{4}$-in. diam electrode was used for $^{5}/_{16}$-in. size welds and a $^{5}/_{16}$-in. diam electrode was used for $^{3}/_{8}$-in. welds. All were used at recommended currents.

Weld Penetration

Since the introduction of submerged-arc welding many years ago, industry in many cases has taken advantage of the increased weld penetration inherent with this process and has accordingly designed joints for smaller welds. Similarly magnetic-flux gas-shielded arc welding, as well as other continuously fed wire processes, has greater penetration characteristics which industry has taken advantage of in many cases.* In this respect, Fig. 4 illustrates the cross section of a horizontal fillet weld with a $^{1}/_{4}$-in. leg size made with magnetic-flux gas-shielded welding and the covered electrode. The much greater root penetration of the magnetic-flux weld can be clearly seen and is characteristic of a process employing carbon-dioxide shielding. Recently Christopher and Becker cited that it is possible to design for fillet welds which are 2 and 3 sizes smaller by employing

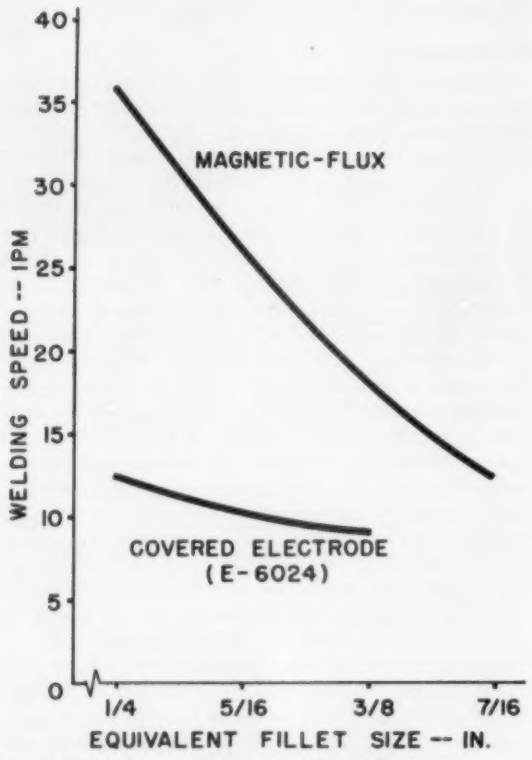

Fig. 5—Magnetic-flux and covered-electrode welding speeds for equivalent size welds

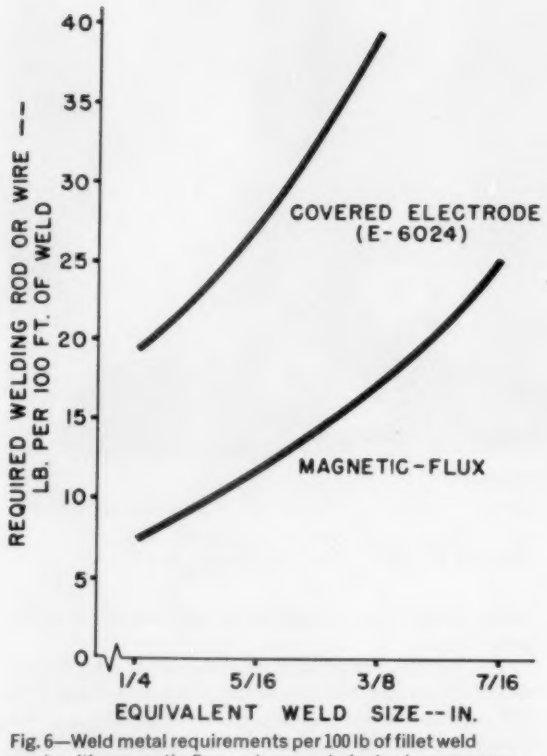

Fig. 6—Weld metal requirements per 100 lb of fillet weld made with magnetic-flux and covered-electrode processes

a continuously fed wire process; such welds will develop the same strength as a much larger covered electrode weld.[3] For the purpose of this discussion, however, fillet welds only one size smaller are compared to covered-electrode welds.

The significance of this data with respect to weld design can perhaps be better understood by referring to Fig. 5. Here are illustrated the welding speeds obtained with both magnetic-flux and covered-electrode welding wherein the magnetic-flux welds are considered equivalent with one leg size smaller. In this case, magnetic-flux welding speeds are three times faster. Thus in Fig. 5 the magnetic-flux welds being one size smaller than covered-electrode welds will exhibit greater strength since, as Christopher and Becker point out, the greater throat thickness develops greater strength. In other words, these welds while smaller will have a greater safety factor in service than comparable covered electrode welds.

Analysis of Costs

Certain material savings are associated with the magnetic-flux process as indicated in Fig. 6, where pounds of welding rod required for 100 ft of horizontal fillet weld of various sizes are shown. The E6024 covered electrode requires about $1^1/_2$ lb of welding rod to a pound of metal deposited with the result that inherently 50% more rod is required per weld. On the other hand, the magnetic-flux weld, which is plotted on the basis of a fillet one size smaller, requires only one-third this amount to make an equivalent weld. Furthermore for a $^1/_4$-in. size weld made with E6024 electrodes, almost 20 lb of welding rod are required for 100 ft of weld, whereas with magnetic-flux only about 7 lb of welding wire are required for the equivalent weld.

The increased welding speeds and lower material requirements of magnetic-flux welding can be translated into specific dollar savings. Thus Fig. 7 illustrates total welding costs in dollars for each 100 ft of horizontal fillet welds of different sizes. Labor was assumed at $2.50 per hr, while overhead was calculated at 150% of labor. Operating factors were 50% for magnetic-flux welding and 40% for covered-electrode welding. Material costs were 18¢ per lb of E6024 electrodes, 17¢ per lb of welding wire for magnetic-flux welding and 33¢ per lb of flux. One-half pound of flux was used per pound of wire, and carbon dioxide at 40 cfh was employed at a cost of 0.015¢/cu ft. A license fee was also included.

The two solid lines in Fig. 7 compare the total costs of covered-electrode and magnetic-flux welding. Note that a fillet weld one size smaller was employed in magnetic-flux welding. The results show that a

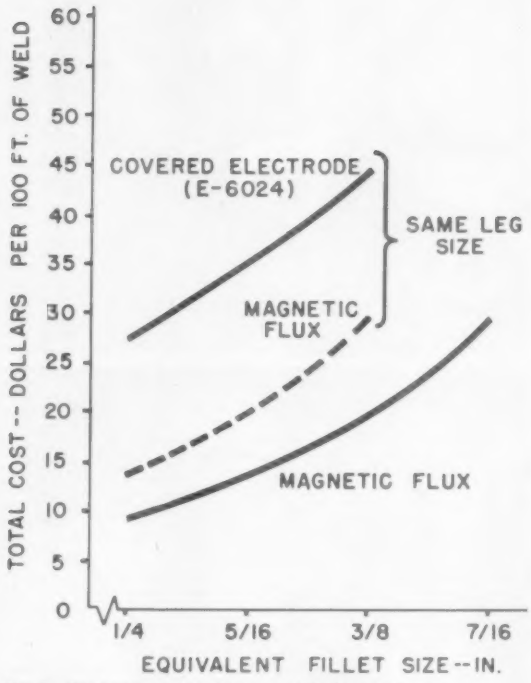

Fig. 7—Cost comparison for magnetic-flux and covered-electrode welding processes

1/4-in. size covered-electrode weld was made at a cost of almost $28/100 ft of weld whereas, with magnetic-flux welding, costs were on the order of $10/100 ft of weld. If costs are calculated on the basis of equal leg sizes, results are as indicated by the broken curve in Fig. 7. Here for equal leg sizes of 1/4 in., total magnetic-flux welding costs are about $14/100 ft of weld, indicating that covered-electrode welding costs are twice as great.

Applications

A variety of magnetic-flux welding industrial applications have already been described in the literature.[3] These include the fabrication of earth-moving equipment, aluminum reduction melting pots and heavy fabricated valve bodies. The process has also been used in tank shops, pressure vessel shops and for the mechanized welding of pipe as well as for the repair of steel castings. The process is still being used on these general types of applications today. In addition, the process has been applied to many new applications in the recent past. Briefly, these can be classified as structural fabrication, the fabrication of high-strength steels, and the erection of field storage tanks.

Structural Fabrication

The fabrication of plate girders for highway bridge use requires welds that must meet various state codes. Either single- or multipass magnetic-flux welding, because of its excellent mechanical properties, fills this need. As an example, Fig. 8 shows the magnetic-flux welding of stiffeners. In this case, intermittent fillet welds of 1/4-in. size are made using 1/16-in. diam wire. Welding speeds are more than twice as great as obtained with covered-electrode welding. The magnetic-flux process, because of its easy starting when using constant potential power, presents no problem to the operator who can make one weld after another without raising his helmet, thereby taking advantage of the continuously-fed electrode. As a further example, another fabricator has found that a switch from E6024 iron powder electrodes to the magnetic-flux process for welding stiffeners has resulted in approximately a 50% cost savings.[4] Also, the process has been used for welding shear connectors and for splicing flanges on this type of work.

Another fabricator has utilized this process for making heavy beams for use in a large car dumper shown in Fig. 9. Although the process produced 1/4-in. fillet welds at speeds exceeding 24 ipm, the

Fig. 8—Welding bridge girder stiffeners with magnetic-flux gas-shielded arc process

Fig. 9—Magnetic-flux welded beams for car dumper

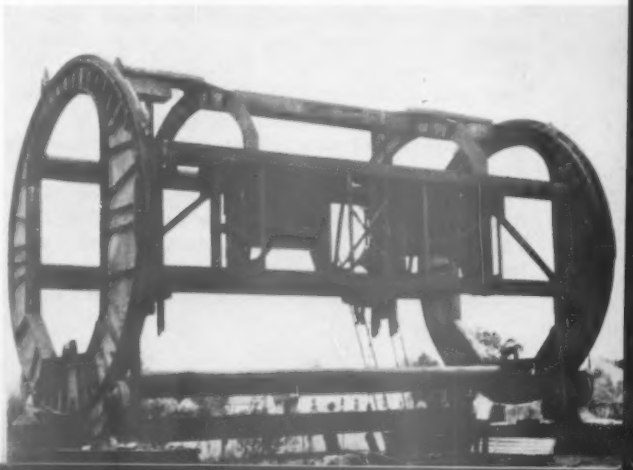

Fig. 10—Magnetic-flux welding of beams for car-dumper track bed

primary reason for utilizing it was to eliminate the need for straightening after welding. This resulted in considerable savings. The actual welding operation appears in Fig. 10 where the operator is preparing magnetic-flux welds on the track bed for a large car dumper. Previous assemblies made with covered-electrode welding developed considerable distortion and were straightened only at considerable expense.

It is generally true that the lower heat input associated with the higher welding speeds of the magnetic-flux process results in less distortion during welding.

Welding of High Strength Steels

There has been a trend to specify higher strength steels for earth-moving equipment in order to develop better performance and to reduce the amount of steel required. The welding of high strength steels calls for weld yield strengths in the order of 100,000 psi and impact properties of 15 ft lb or better at about −50 deg. One problem often experienced in welding of these steels is that of cracking. Nonetheless, magnetic-flux welding with an inexpensive wire and the same welding flux employed for mild-steel fabrication does an excellent job on T-1 steel. The resulting welds are crack-resistant, and mechanical properties meet the needs of fabricators. Moreover welding speeds are approximately two to three times faster than obtained with low-hydrogen electrodes. As a result, the fabricator can use the process to great advantage.

Typical results obtained on high-strength steels with magnetic-flux welding appear in Figs. 11–13. Figure 11 illustrates an off-the-road rear dump trailer used for hauling rock under rugged conditions. This unit is fabricated from high-strength T-1 steel by means of the magnetic-flux process; no weld failures have occurred in service. Figure 12 shows

Fig. 11—Magnetic-flux welded dump trailer

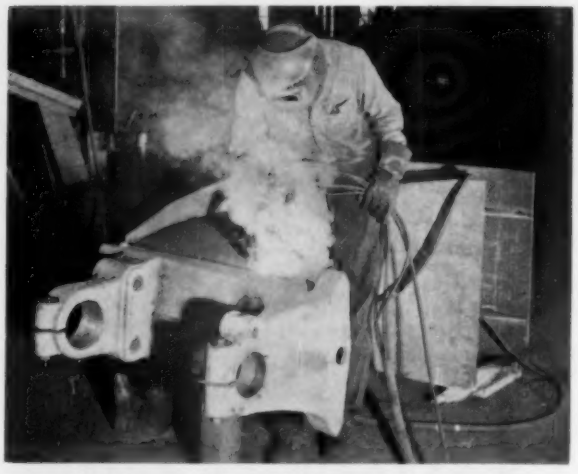

Fig. 12—Use of magnetic-flux welding for joining steel plate to swivel casting

magnetic-flux welding being applied for the purpose of joining $^1/_4$-in. steel plate to a heavy swivel casting. Figure 13 shows the process being used during final assembly of the hopper. For this application, $^1/_{16}$-in. diam welding wire is used at a current of approximately 300 amp.

Field Erection

One of the most difficult applications for any semiautomatic process is outdoor welding where adverse climatic conditions such as wind, rain and snow may be encountered. Magnetic-flux welding because of its greater resistance to drafts, moisture and rust has proven outstanding under field conditions. Furthermore, the ability to weld in all positions and the high deposition rates have permitted fabricators to develop considerable cost savings by comparison to welding with covered electrodes.

As evidence, one of the first applications of magnetic-flux welding erected storage tanks was the erection of three oil tanks, each with a diameter of 100 ft and holding about 6,300,000 gal. The three tanks were erected with only 700 man-hr of magnetic-flux welding compared to the 1850 hr normally needed for covered-electrode welding. In addition,

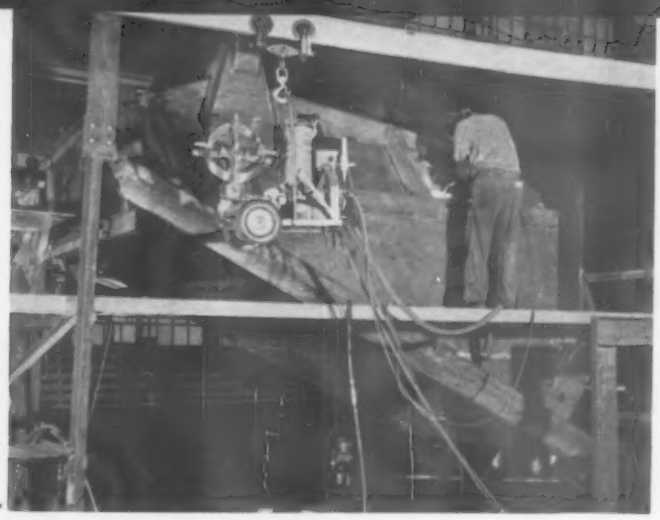

Fig. 13—Application of magnetic-flux welding to assemble hopper

cleaning requirements were reduced considerably. In one test, all joints were checked by radiographic examination in accordance with API Standard 12C, and no defects appeared in any vertical or horizontal seams welded with the process. The lead photograph shows the operator making a horizontal weld between the first and second rings of the tank. Here $^{3}/_{64}$-in. diam welding wire was used for the vertical and horizontal seams. A welding current of approximately 180 amp was employed on the vertical seams, and about 250 amp were utilized on the horizontal seams.

Another fabricator has employed four of these machines for making horizontal welds in a 5,000,000-gal water storage tank. On horizontal seams using the same edge preparation as employed for covered-electrode welding, welding speeds were approximately three to five times faster. In subsequent work using square butt spaced joints, welding speeds were six to ten times faster than developed with covered-electrode welding. Figure 14 shows an operator making a horizontal weld with a machine mounted on a carriage; Fig. 15 is an over-all view of the welding operation. Here root passes were made using a welding current of 280 amp and $^{3}/_{64}$-in. diam welding wire. Cover passes required a current of 240 amp and all together the magnetic-flux process required fewer passes than covered-electrode welding, thereby reducing cleaning. Moreover because less distortion was obtained with magnetic-flux welding, less time was required in setting plates in place when erecting the tank.

Conclusion

Magnetic-flux gas-shielded arc welding has gained widespread acceptance for application to mild steel. This has been particularly true in structural fabrication as well as field erection and has extended to the welding of higher strength materials, particularly T-1 steel. Much of this growth is to be attributed to new developments which have increased the speed while lowering the cost of welding and have effected substantial improvements in the performance, reliability and cost of equipment.

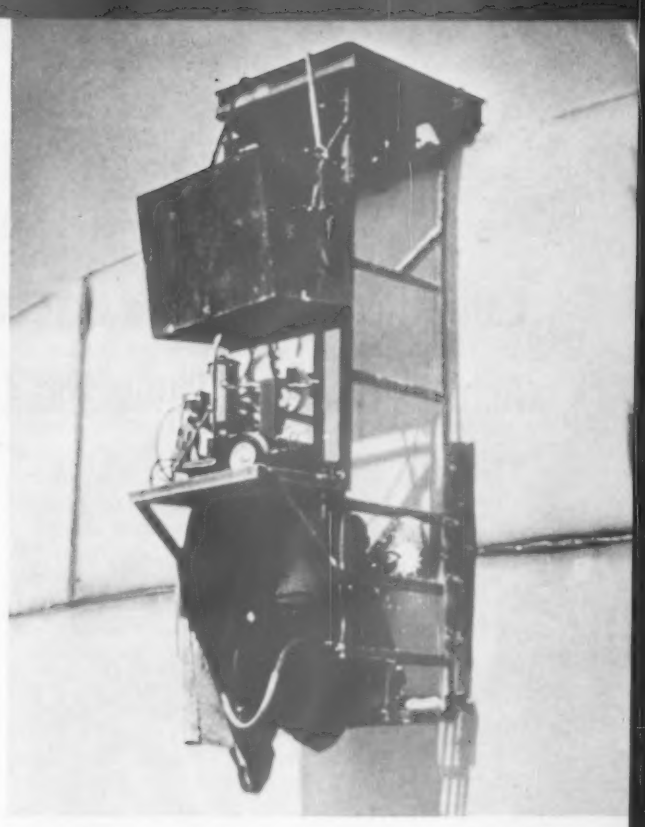

Fig. 14—Close-up of magnetic-flux welding horizontal seams in 5,000,000-gal water storage tank

Fig. 15—Over-all view of magnetic-flux welding operation for field erection of water storage tank

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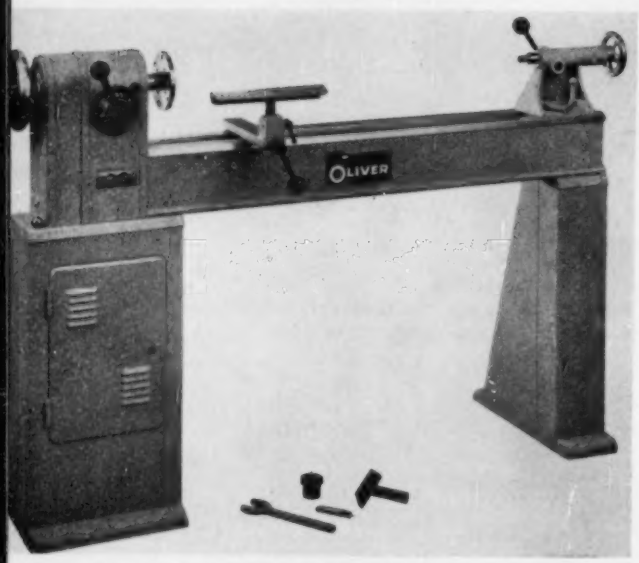
The case history of a practical problem and its solution wherein

Lathe Redesign in **Welded Steel** Achieves Cleaner Lines and Lower Cost

BY ERNST DUESING



Redesigned arc-welded steel lathe for wood turning and metal spinning

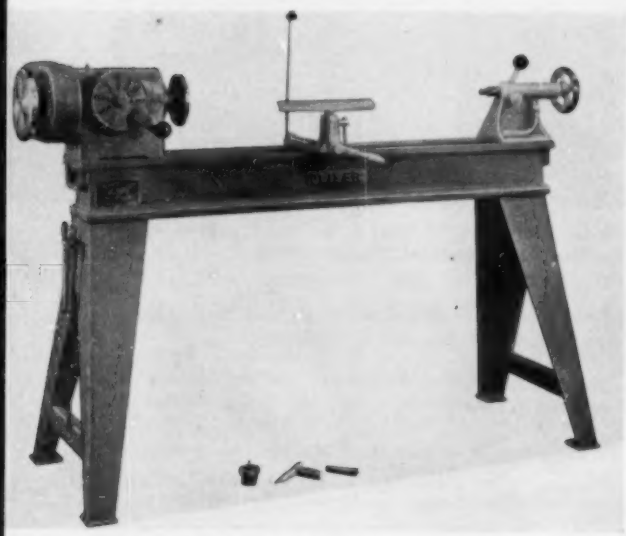


Fig. 1—Originai cast-iron lathe

The Problem

Since the turn of the 20th century, the Oliver Machinery Co. has been building woodworking machinery of every size and description. Many of the smaller types of machines are found in high schools and vocational schools throughout the country. However, in recent years much of this type of business has been lost to competitors. A case in point was the 5-ft wood turning and metal spinning lathe shown in Fig. 1 where the competition has marketed a similar lathe at a substantially lower price.

Efforts were made to meet this competition by replacing some of the more expensive castings in the lathe with weldments. This being only a half-measure, it achieved only half success. As a result, sales of this particular machine continued to dwindle to only a fraction of their former volume.

Lathe Bed Redesign from Cast Iron to Steel

A decision was made to recapture the market on the lathe in Fig. 1. To do this involved the choice of two alternatives: either to build a cast iron design of lower quality, as competitors have done, or to produce a lathe equally as good or better but of less expensive design—lead photograph. With a 50 year reputation of building only the highest grade of machine tools, there was no inclination to change this policy. Experience with weldments, although limited in scope, pointed the way to a new and more efficient design.

Although arc welding is used in every major part of the new lathe, with exception of the tailstock which eventually will be changed over, it may be of interest to describe in somewhat greater detail the new welded steel bed and to outline the reasoning which led to the new design. Since the welded lathe bed performs precisely the same function as the old cast iron one and in its dimensions is practically identical to the former, the new design offers an excellent opportunity for comparisons as to cost, strength and appearance.

The factory cost of the 5-ft cast iron lathe bed

ERNST DUESING is Supervisor, Oliver Machinery Co., Grand Rapids, Mich.

Based on a $10,000 First Award paper submitted in the 1959 Machine Design Competition sponsored by The James F. Lincoln Arc Welding Foundation, Cleveland, Ohio.

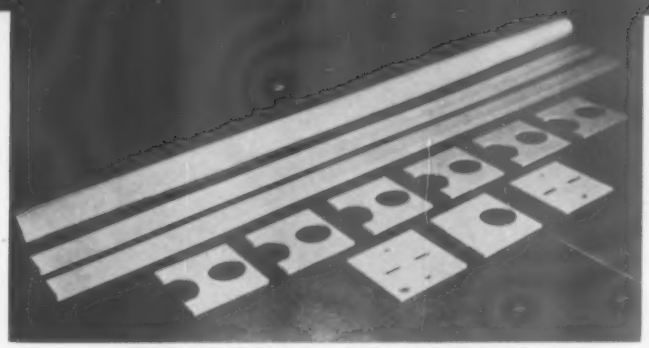


Fig. 2—The twelve components for making up welded steel bed, including $2^{3}/_{4}$-in. OD tubing and $^{5}/_{16}$-in. plate punched cross members

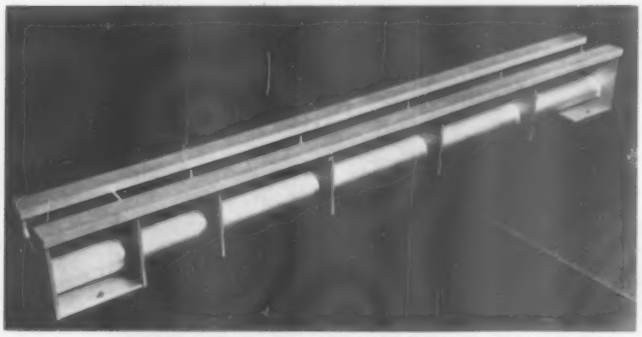


Fig. 3—Finished lathe bed weldment before addition of side aprons—ways are hardened and ground $^{3}/_{4}$- × 2-in. cold-rolled steel

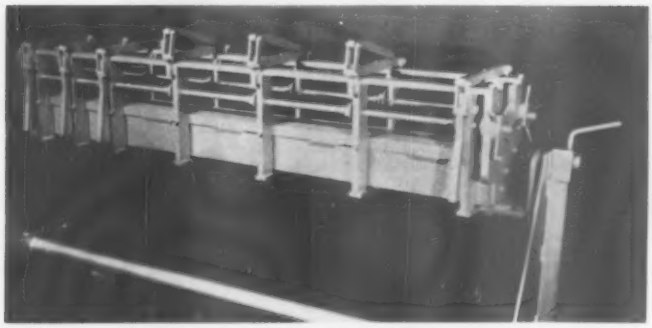


Fig. 4—First welding fixture, locates cross members on tubing for welding—can be rotated on trunnions for downhand welding

originally was $55.90. This is, of course, a rather large item in a machine that for competitive reasons should sell for not more than $500. Therefore, this part received first attention in the redesign program.

In the effort to reduce this cost, a new cast iron bed—plainer in appearance and lighter in weight—was designed. However, the cost of this unit, cast and machined in the company's own shops, still ran to $47.25. Since modernizing the foundry as well as constructing new patterns and using the latest equipment for molding and casting did not reduce costs below this point, attention was turned to an arc-welded steel design.

At the start, a common mistake was made. Several futile attempts were made to build a steel lathe bed too closely along the lines of the old cast iron model. These designs were either too costly, lacked strength or suffered from an appearance standpoint. Only when the problem was analyzed more thoroughly did progress begin to be made. A lathe bed for the redesigned machine needed to consist of nothing more than two parallel and accurately machined ways, which were connected and supported by enough iron to resist bending and twisting. In spite of its heavy weight, a conventional cast iron lathe bed is a poor design to withstand torsion. This fact is well known to the machinist who has to plane the bed; it also becomes obvious when a lathe of this type is bolted to an uneven floor, without carefully leveling and shimming it.

Basing the redesign on these known facts, the solution to the problem became quite simple. For greater torsional rigidity, resort was taken to inexpensive seam-welded steel tubing. For accurate ways that required little machining, standard flat cold rolled steel was indicated. These items, plus two base plates also made of standard cold rolled steel and a number of heavy stampings used as cross members, were joined by arc welding. The lathe bed and its components at this stage are shown in Figs. 2 and 3.

The new steel design proved advantageous in other respects. The tubing not only resists torsional stress to a high degree but also provides considerable strength against bending. Therefore, little extra tooling was necessary to convert the standard lathe into a gap lathe, with only minor loss in strength and greater capacity than competition could offer with a cast iron bed. No additional tooling at all was needed to build lathe beds in various lengths—an absolute necessity to meet market demands. None of these features was possible in a cast iron bed without additional costly patterns.

Role of Welding Fixtures

Welding fixtures were needed, and much thought went into the two that were built to give accuracy and speed in assembly of the bed. Here too it should be emphasized that arc welding played a most important role. Standard hot and cold rolled steel is used for all components of the fixtures, and it is likely that neither could have been built without the aid of welding.

The most popular 5-ft lathe bed, without gap, is made of 12 pieces. Two requirements had to be met. First, it was necessary to make the two ways, of $^{3}/_{4}$ x 2-in. cold rolled steel, perfectly straight and equally spaced in two parallel vertical planes so that no machining of the four side faces was necessary. The horizontal top face of the rails could be surface ground easily, an inexpensive operation which adds to the appearance of the bed. Therefore, the tolerance requirement here was not so critical. The other demand, of course, was ease of placing the various parts into the fixture and ready removal of the welded bed. Sometimes actual welding time becomes the lesser of the two operations.

The first fixture, as shown in Fig. 4, locates the seven

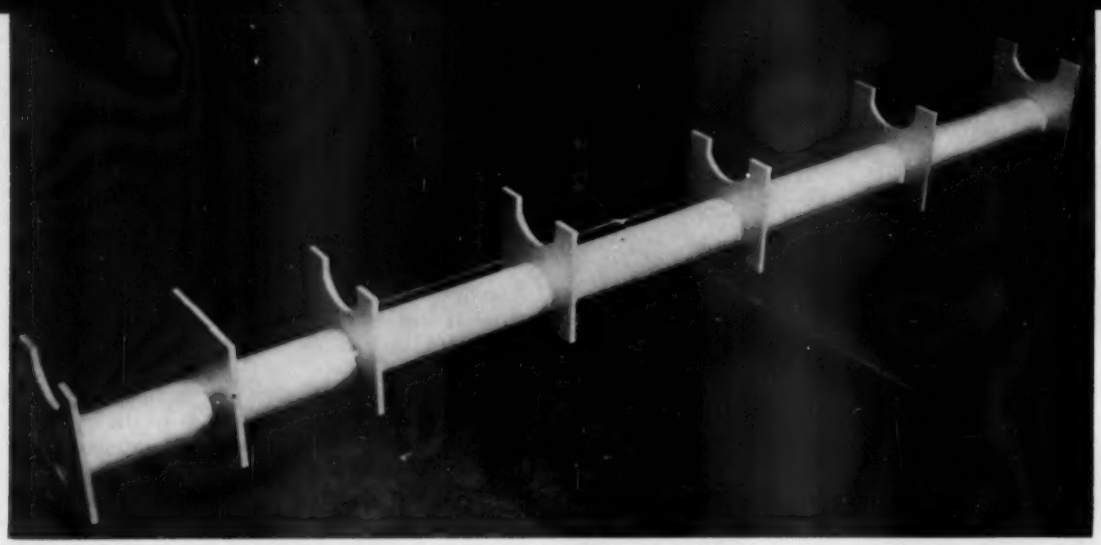


Fig. 5—Gusset plates are welded on both sides to the tubing, with welds being omitted across the top and bottom portions of the tube

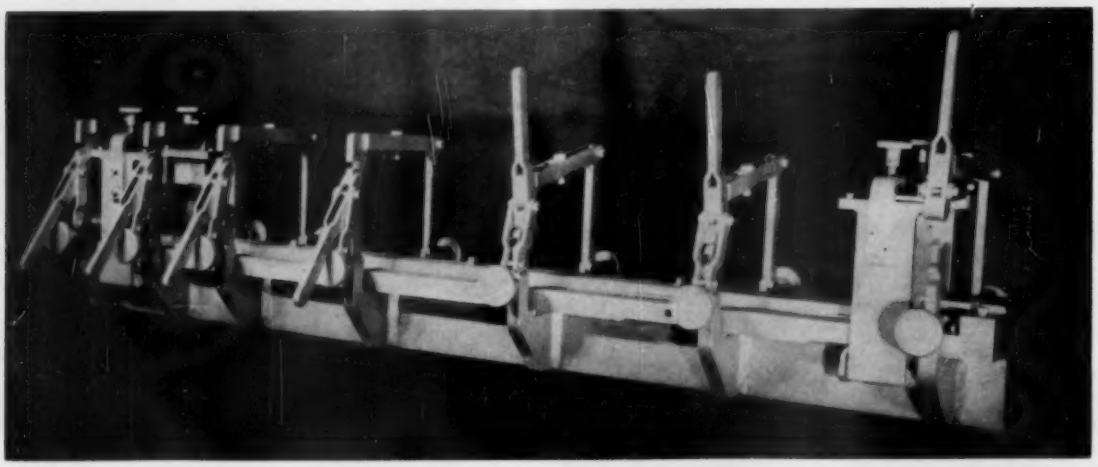


Fig. 6—Second welding fixture in which the two ways are welded to the gussets and bottom plates are welded to the underside at either end

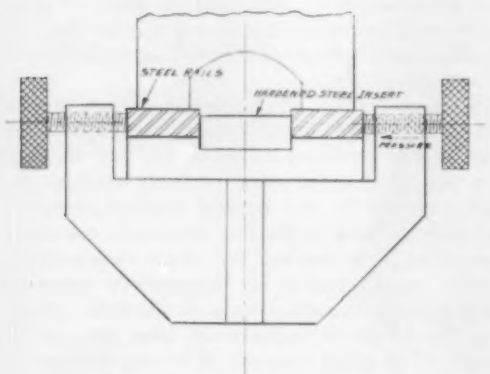


Fig. 7—Cross section of a portion of the inverted bed in the welding fixture, indicating how ways are clamped against the central spacing bar

crosspieces around the tubing. Here attention was concentrated on accurate spacing and on keeping all top surfaces of the gussets in the same plane. A possible misalignment of the crosspieces sidewise was not important.

The gussets are welded on both sides, but only on the two opposite nearly vertical faces of the tubing. By omitting welding on the top and bottom of the tubing, any possible distortion was minimized in the plane that had to be kept straight. Sufficient strength was built into the welding fixture to straighten the tube while it is being welded. By so doing it was possible to specify standard tubing with commercial tolerance for straightness ($^1/_{16}$ in. per 5 ft length) without paying a premium for closer tolerances.

As may be seen in the illustration of the first welding fixture, only two knobs (located at the right end), clamp all seven gussets against the vertical

locating faces. Quick-acting toggle clamps straighten the tube and align the plates horizontally. The fixture rotates to permit down-hand welding.

After this subassembly, which is illustrated in Fig. 5, is allowed to cool following welding and to find its normal position, it is placed in the second welding fixture for welding of the bottom plates and the two parallel top rails—Fig. 6. Here again the welding process is adapted to eliminate a costly machining operation. Like most other cold rolled steel, the material used for the top rails is seldom perfectly straight. Therefore, as in the first welding step, the fixture is used for straightening the bars. Pressure is applied at seven points on each side to clamp the rails securely against a hardened and accurately ground spacing bar. This bar is inserted in the welding fixture and due to the strength of the fixture imparts its accuracy. A cross section of the setup is shown in Fig. 7.

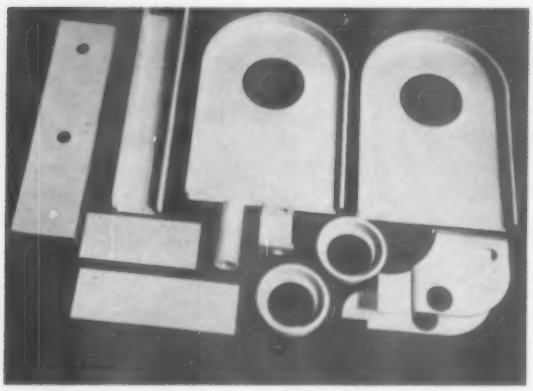
Undoubtedly it would have been possible to counteract any distortion of the rails in the horizontal plane. The welding of the rails to the gussets causes a slight dip toward the welds. Preforming the rails in the fixture would have overcome this distortion. However, since an inexpensive grinding operation takes care not only of this deformity but also enhances the appearance of the exposed surface, a slight unevenness here was not objectionable. This variation in height, or surface irregularity, has proved to be less than 0.010 in.

It is entirely possible and practical to hold the ways completely straight and parallel to one another within 0.001 in. for the entire length of the bed. This accuracy is equal to or better than that obtainable on a planed cast iron bed.

The individual strength of all the parts used in the bed and the manner in which these components are joined makes normalizing of the finished product unnecessary. It is felt certain also that there is less creep in this steel bed than in a regular cast iron bed which has had no time to age. Only a few thousandths of an inch had to be removed by grinding from the top of the rails and from the bottom plates.

Careful tests have shown the welded bed to be far stronger and three times as resistant to torsional stress when compared with its cast iron counterpart.

It was felt that prospective users might as yet not be ready for such a radical departure from the appearance of a conventional lathe bed. Therefore, a 16-gage embossed steel panel was welded to each side to conceal the internal structure. These panels are located with the help of notches along the top edges. These locating notches required the accurate spacing of the gussets in the bed, as mentioned earlier. While adding little to the strength of the bed, the panels do cover over the welding and thereby eliminate all need for cleaning the welds.



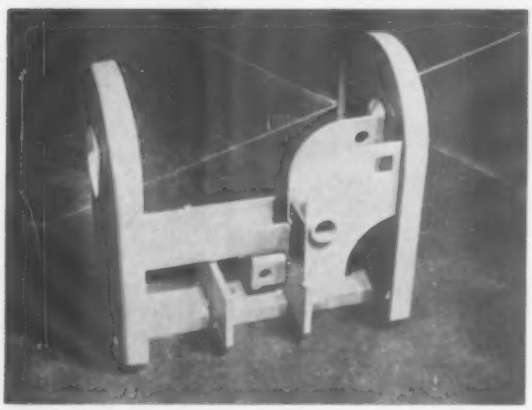


Fig. 8—Eleven components of standard steel shapes and stampings (top) make up the headstock weldment (below)

Cost Comparison

Following is a comparison of weight and cost of the two types of beds. It should be pointed out that the labor costs shown for the steel bed are based on only a few pieces. It is reasonable to assume that the cost of the welded steel design will be reduced still further. The details:

Cast Iron Bed	
Material: 156 lb at $0.17	$26.52
Labor: Planing, grinding, drilling 2.764 hr at $7.50	20.73
	$47.25
Welded Steel Bed	
Material: 102 lb at costs varying from $0.096 to $0.158/lb	$13.65
Labor: 1.45 hr, including 0.65 hr welding time, at $7.50	10.87
	$24.52
Weight saving	34.5%
Cost saving	48%

Lathe Headstock Changeover from Cast Iron

As far as the headstock of the old lathe is concerned, changes had been made some time ago to permit the use of some welded steel. Careful analysis indicated that a further reduction in cost of the cast iron headstock was not possible without lowering

its functional quality. So a change was made to a complete welded steel unit.

The headstock is designed to give variable spindle speed, normally from a low of 600 rpm to a high of 3600 rpm. This speed range can be decreased or increased, but speeds over 3600 rpm are not considered safe for school training purposes. The variation in speed is obtained through the use of variable-pitch sheaves.

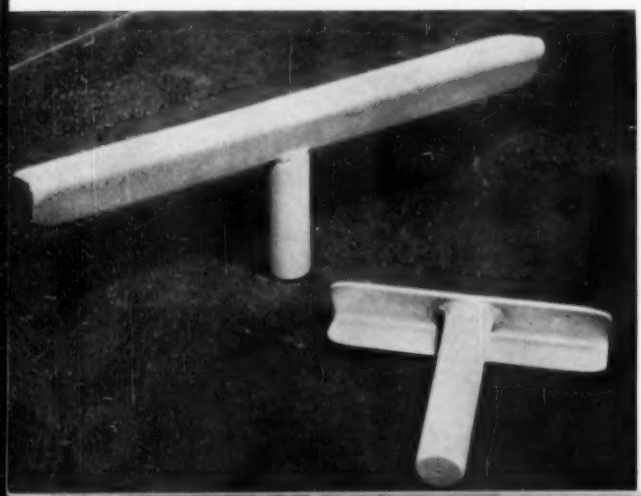
Ability to use standard steel shapes and low cost stampings in the completely arc-welded headstock, to place these parts in the desired location, and to weld them into a rigid unit made it possible to employ an extremely simple shifting mechanism which is free of vibration through its entire speed range. Simplicity of the new design has elicited favorable comment from a number of educators in various parts of the country who have been shown a hand-made model of it.

Eleven components are used to make the unit as shown in Fig. 8, which also illustrates the finished weldment. A spindle, ball bearings, pulleys, actuating arm, speed dial, shafts and cams, cover and several small parts make up the complete headstock. Some of these elements themselves are welded.

The main unit is welded in several stages. First, the ball bearing housings are welded into the end plates. Both parts are punched and formed from $^3/_{16}$-in. thick sheet steel. Next the bearing sleeve is welded into the dial bracket. Then dial and pivot brackets are joined to the channel section. Finally, all parts plus the headstock tongue are welded to complete the unit. Separating these operations simplifies the welding fixtures, ensures better alignment of the various parts, and makes for better and more accessible welds in less time.

On the finished headstock, costly machining operations again are held to a minimum. The tongue, made of $^5/_8$ x $2^1/_2$-in. cold-rolled steel, forms the base of the part and fits accurately between the two rails of the lathe bed to locate the head accurately. Only the two ball bearing housings are bored after welding to assure proper bearing fit and to provide for the correct location of the spindle.

Fig. 9—Welded steel tool rests, 12- and 6-in. lengths, with 1-in. shank—upper portion formed from 10-gage sheet steel



Cost Data

Total cost of the weldment is $15.45, breaking down into $3.75 for material and $11.70 for labor. The latter includes 1.03 hr for shearing, punching, forming, drilling, tapping, etc., and 0.53 hr for welding, all based at $7.50/hr. By comparison, cost of the former cast iron headstock was $27.50, of which $12.13 was material and $15.37 labor.

On both the headstock leg and tailstock leg, arc welding is limited to the joining of the corners of the foot section.

Tool Rest

Aside from the arc-welded motor bracket, two other parts formerly were of cast iron—the tool rest and the tool rest holder. The cast iron tool rest in particular was a nightmare for the foundry department. It is made in not less than 24 different models, each requiring a different pattern. The great number is due to the variation in length (from 6 to 60 in.), to the size of the shank (1, $1^1/_4$ and $1^1/_2$ in.) and to the style (single pole, double pole and rectangular). Now, only four adjustable welding fixtures are required to arc weld all 24 styles and sizes.

The upper angular part of the rest in Fig. 9 for supporting the tool while turning a piece of wood or spinning a piece of metal is of 10 gage sheet steel. Its cross section remains the same throughout, only the length varying.

Cost figures again show the great savings that can be realized by replacing a high-priced casting with a simple yet stronger welded steel assembly. On a size that is produced 200 to 400 at a time, unit cost for the cast iron rest was $2.25, of which $0.46 was material and the rest labor. In welded steel, unit cost amounts to only $1.20 of which $0.24 is material and the balance labor. Total labor time was only 0.128 hr.

Conclusion

Based on experience gained in developing a welded steel replacement for a difficult and costly casting at numerous times, practically any machine component that is now cast can be changed to welded steel, resulting in a better part at lower cost. The solution to such a problem may not always be obvious. However, a thorough knowledge of all the production facilities available in any particular shop usually suggests a method approach in solving each separate and different problem.

When sufficient cost data had been collected on the new wood turning and metal spinning lathe, described in this paper, it became evident that a price on it could be set 35% lower than a cast iron lathe of less capacity. The price is below that of competition and also assures a far safer margin of profit than was possible on the former model. The 35% reduction becomes even more noteworthy when it is considered that the cost of many parts such as motor, controls, bearings and other items has remained the same or gone up.

Practical Welder and Designer

Tungsten-Arc Welding Saves Trucking Firm $3000

Bell Lines, Inc.—a trucking company in Charleston, W. Va.—had accumulated an assortment of damaged aluminum truck parts valued at $3000. These parts were considered a total loss until a representative of the Virginia Welding Supply Co. was called to inspect them. After an examination of the parts the trucking company was told that they could be repaired by tungsten-arc welding. Two days after a tungsten-arc welding torch was installed, every discarded part had been reclaimed. This one salvage operation paid the entire cost of the torch and power unit plus the overhead for labor and consumables.

Prior to turning to tungsten-arc welding, Bell Lines contracted local welding shops for repairs on damaged aluminum parts. This permitted a slight dollar saving, but a loss of time. In many instances when time was an important factor, the damaged parts would be scrapped and replaced with new factory parts.

Now, Bell Lines uses the tungsten-arc welding torch for 75% of all their welding repairs. They often repair aluminum trailers while still attached to the cab. If these repairs are minor, the job is usually completed in a single pass. Whenever large breaks are encountered, the parts are first tack-welded in place and then filler metal is added to finish the job.

Dollar savings on parts has been tremendous since the new equipment was installed in the maintenance shop. A $450 aluminum transmission case can be welded in approximately 3 hr at a cost of less than $40. Only $1/2$ hr of labor is required to salvage a $125 bell housing. A $130 aluminum trailer wheel can be rebuilt in about 2 hr at a cost of $20. If these wheels were rebuilt at an independent shop, the job would cost $55 per wheel and would take approximately four days before they would be returned to service.

Since Bell Lines has been using the tungsten-arc welding, repair bills have been reduced considerably. They estimate that this one torch will eventually handle 95% of their repair work because truck and trailer manufacturers are using more aluminum parts every year.

Fig. 1—A tungsten-arc welding torch is used to weld a broken aluminum spring hanger. This part costs approximately $80 but was repaired for $10.

Fig. 2—Here, a welding operator welds a damaged front cross member. This is a typical repair job for the maintenance men of Bell Lines, Inc.

Based on a story by the Linde Co., New York, N. Y.

Redesign Reduces Costs

Stearns Magnetic Products, Milwaukee, Wis., has turned to welded construction to upgrade its line of scrap handling magnets. Positive results of design improvements and simplification of manufacture are a 10% reduction in weight, 9% reduction in cost, and elimination of many of the problems related to customizing the product and meeting tight delivery schedules.

The new design, initiated to produce a magnet for the scrap industry that would sell at a lower price, incorporates low-carbon plate for the bulk of the material used in the housing. This low material cost, as compared to that of the castings, processed with production fabricating techniques has been primarily responsible for achieving the design goal. Weight reduction resulted from the use of aluminum coil windings, although steel construction was also partially responsible.

Conversion to fabrication by Stearns has resulted in great flexibility in manufacturing procedures. The major parts are welded together with E-6024 type electrodes and can be readily modified and tailored to meet customer needs. Where conditions demand, very short delivery schedules can be met at no additional expense since it is not necessary to seek special production scheduling arrangements with the local foundry.

Function of the magnet demands that a nonmagnetic material be placed in a position that will separate the inner pole from the outer pole. This protects the magnet coil from mechanical damage. This performance requirement, combined with the necessity to provide waterproof protection for the electrical parts, proved a problem and necessitated the development of a complex sealing arrangement for the cast design. The natural seal of a welded joint combined with the ability to join dissimilar metals eliminates this problem. A bead is deposited around the inner and outer diameter of the nonmagnetic manganese protection shield using a stainless steel electrode. This joins the parts and seals the area.

Another feature resulting from the weldability of the new design concerns maintenance and repair. Areas that are worn or demand repair can be readily field welded. Worn areas can be easily returned to original size and condition. It is even practical to reduce wear rate in the areas receiving excessive abuse by overlaying the new or rebuilt units with a material that will withstand abrasion better than the original material.

Fig. 1 (Left)—Newly designed scrap handling magnet—fabricated with E-6024 type electrodes. Fig. 2 (right)— Old design scrap-handling magnetic—largely fabricated with bolts

Based on a story from the Lincoln Electric Co., Cleveland, Ohio.

An Aluminum Back-Up Bar for Automatic Metal-Arc Gas-Shielded Welding

BY C. M. JENKINS

In 1952 when production began on airframes for the famed U. S. Army Redstone missile, welding requirements would have been termed "fantastic." The intensive quality control program is a story in itself. But typical is the fact that every one of the more than 3000 in. of welding on this and other missiles was X-rayed and microscopically examined for flaws such as cracks, porosity and foreign inclusions.

Before each automatic metal-arc gas-shielded weld was made on a production part, a test plate approximately 30 in. long was run and processed through the X-ray laboratory and through physical tests. This gave the highest possible assurance of quality in the product. The standard was "perfection." At the same time faster production speed and lower costs became increasingly important. These and the demand for "perfection only" welding quality led to the development of a new aluminum back-up bar—Fig. 1.

"Short runs" are typical of high-precision missile and rocket welding. Previously, solid back-up bars of stainless steel were used until a switch to aluminum back-up bars with a small stainless steel insert with excellent results. Also previously, much shop time was devoted to removing and repairing the all-steel bars which were far too expensive to throw

C. M. JENKINS is with the Reynolds Metals Co., Sheffield, Ala.

away when they became burned and pitted. With development of the new back-up bar, however, it became necessary only to pull out the small stainless steel insert which is inexpensive enough to throw away. It was found that the inserts could be replaced for less than half the cost of repairing the all-stainless back-up bars previously used. And since it is much quicker to pull out only the insert rather than the entire bar, there was a significant saving in production time.

An increase in weld quality occurred with use of the new back-up bar. Part of this increased quality came from the faster heat dissipation through the aluminum back-up bar as well as through the stake welding machine, itself, which is also made of aluminum. As the thermal conductivity of aluminum is almost eight times that of stainless steel, cooler operation and a resulting reduction in transverse cracking of the weld bead were also obtained.

The welds to be made on this stake welding unit were the longitudinal welds that formed the 220-in. long sheets of 5086-H34 aluminum into 70-in. diam cylinders that go to make up the giant fuel tank of the rockets. The 90-in. long aluminum holder was machined from 6061-T6 aluminum and designed so that the wide flat bottom of the holder would transfer heat into the body of the main welding fixture, which is also aluminum.

The "T" shaped stainless steel insert could be machined or extruded but had to have a slip fit into the aluminum holder so that the inserts could be removed easily for cleaning after each weld or changed for different groove size or shape. These inserts were made from nonmagnetic stainless steel. Grooves of various sizes and shapes could be machined into the inserts to accomodate the different thicknesses of material to be welded.

One of the most successful of the grooves was the vee groove shown in Fig. 2. The approximate size of groove at the widest point was two times the thickness of the material to be welded. The groove was a 52 deg angle vee. This vee allowed the molten metal forming the penetration bead of the weld to cool from the sides and bridge over the vee by surface tension of the molten metal; the result was a clean smooth drop-through uncontaminated by dirt or other foreign material that might be caught in the backing groove. Since the vee was not entirely filled with weld metal, a natural escape tunnel was provided for unwanted gases generated during the welding process, reducing porosity.

The normal hold-down pressure of a stake welding unit of this type provided the force to hold the sheet being welded together with the insert and holder into one firmly held assembly so that, when the weld was made, the heat was quickly transfered through the small cross section of the "T" shaped insert into the massive aluminum holder.

The load, weld and unload cycle of approximately 15 min gave a fixture of this type ample time for the heat to be evenly distributed into the fixture in time for the next weld.

Variations from the original flat bar that accepted flat sheet was made. This bar was designed to accommodate a wide aluminum extrusion with integral stiffening flanges—Fig. 3.

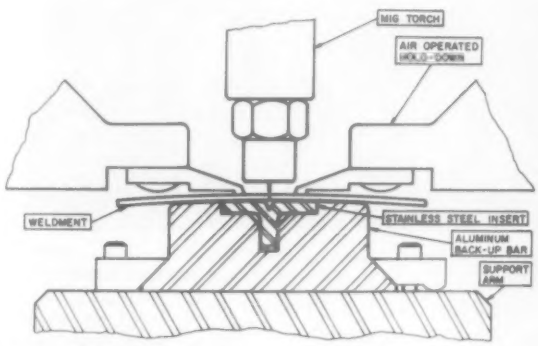


Fig. 2—Cross-section of stake welding unit utilizing aluminum back-up bar as shown with vee groove insert which has proved highly successful

Fig. 1—Aluminum back-up bar with stainless steel insert for metal-arc gas-shielded welding in high precision production work

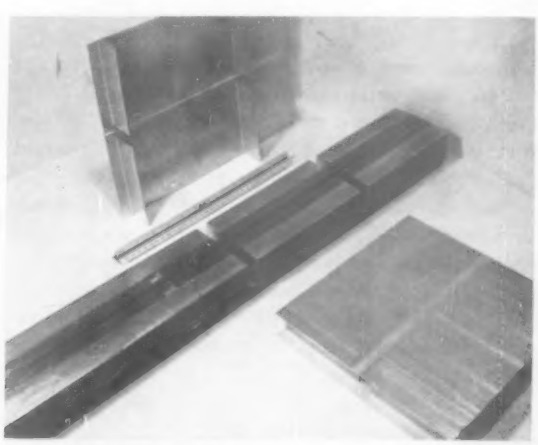


Fig. 3—Aluminum back-up bar shown with two sample test plates as part of a non-missile welding project; flanges on the welded sheet are integral stiffening rings extruded as part of the sheet and the approximately $^{3}/_{4}$-in. gap is filled by an aluminum splice plate

Materials are being hoisted in a bucket to the machinery rooms located on the topmost part of the new building

UNITED ENGINEERING CENTER

Honor Sections

Section	Goal, %	Section	Goal, %
Oklahoma City	125	Long Beach	100
Mahoning Valley	113	Louisville	100
Holston Valley	109	Madison-Beloit	100
Cincinnati	104	Western Mass.	100
Hartford	104	Maryland	100
Kansas City	102	Nashville	100
N. E. Tennessee	102	New Hampshire	100
Puget Sound	102	New Jersey	100
Tulsa	102	N. Central Ohio	100
Baton Rouge	101	North Texas	100
Colorado	101	Northern N. Y.	100
Detroit	101	Olean-Bradford	100
Niagara Frontier	101	Pascagoula	100
Providence	101	Philadelphia	100
Rochester	101	Richmond	100
San Diego	101	Salt Lake City	100
St. Louis	101	San Antonio	100
Birmingham	100	Sangamon Valley	100
Boston	100	Santa Clara Valley	100
Bridgeport	100	Syracuse	100
Chattanooga	100	Toledo	100
Dayton	100	Wichita	100
Eastern Illinois	100	Worcester	100

Pledges Needed to Meet Goal

Section	Needed	Section	Needed
Mohawk Valley	100	New Orleans	390
Tri-Cities	100	South Florida	395
Albuquerque	150	York-Central Pa.	435
Anthony Wayne	150	Fox Valley	450
Shreveport	195	Saginaw Valley	460
Arizona	200	Lehigh Valley	475
Nebraska	200	Portland	485
Washington, D. C.	200	Indiana	490
New York	218	Stark Central	495
Carolina	245	Columbus	790
Northwestern Pa.	280	Long Island	800
J. A. K.	295	Northwest	822
Iowa	300	Milwaukee	927
Michiana	300	San Francisco	1154
Mobile	300	Cleveland	1155
Peoria	340	Houston (and Sabine)	1540
Susquehanna Valley	350	Chicago	1640
Western Michigan	350	Pittsburgh	2163
Iowa-Illinois	370	Los Angeles	2825

Several new sections appear on the Honor Roll for having achieved 100% or better of their goal. However, AMERICAN WELDING SOCIETY pledges stand at 66% of goal.

Mid-winter Progress

Subfreezing weather and a desire to hibernate has not prevented construction progress on the United Engineering Center during a mid-winter cold wave.

Workmen are busy installing elevator machinery and a heating/cooling system for the entire building. Six high-speed elevators, when completed, will whisk engineering society employees and visitors to their offices in seconds. Two additional units will be in reserve for future building expansion. A combination heating and cooling system is being installed throughout the building to provide adequate heat in winter and cool air in summer.

Society News

Plans for AWS Annual Meeting Include Ladies' Program

Ladies will find 1961 their year at the 42nd Annual Meeting and Exposition. They will find New York City a "Mecca" for visitors with tourist attractions ranging from the Statue of Liberty to Central Park.

There are more than 20,000 eating places in the city, while many visitors think of theatre when they think of New York. Tiny shops to giant department stores number in the hundreds and offer wares from all over the globe, including the latest fashion creations. To give an idea of what is in store for the ladies, here is the tentative schedule:

Monday, April 17th—Tour of United Nations. Lunch in Delegates' Dining Room.

Tuesday, April 18th—Breakfast and Fashion Show at B. Altman's.

Wednesday, April 19th—Coffee Hour. Radio City Music Hall. Rockefeller Center Tour. RCA–NBC Television Studio tour.

Thursday, April 20th—Free day for shopping or individual tours.

Other social activities include the President's reception, with an outstanding entertainment program.

While everything possible is being done to make the 42nd Annual Meeting and Exposition a memorable event for the ladies, plans are being finalized for other events, including plant tours for AWS members and the presentation of 66 technical papers at Meeting Headquarters in the Commodore Hotel.

A highlight of the Meeting will be the Adams Lecture by Henri P. Granjon, chef de service, Institut International de la Soudure. He will discuss "Studies on Cracking and Transformation in Steels During Welding," based upon work done by members of Subcommission B of Commission IX of the International Institute of Welding.

Another big Welding event will be the Welding Show, in the Coliseum, which promises to be the largest ever. Because of New York's convenient location, attendance at the Show is expected to reach 18,000. Exhibitors are amassing more than $3 million worth of welding equipment for display at the Coliseum.

Dining room of B. Altman & Co. where AWS ladies will be served breakfast before viewing a Fashion Show at the Fifth Avenue store

Papers by IIW Authors to Be a Highlight of April Technical Sessions

The International Institute of Welding will be breaking precedent when it holds its Annual Assembly in New York City, April 11th to 19th. An equally precedent-breaking occasion during the following week will be participation by authors from abroad in three AMERICAN WELDING SOCIETY technical papers sessions which are being sponsored by the IIW as a consequence of its participation in the 42nd Annual Meeting of the AWS.

The Authors

Nine papers are involved, with 12 individuals from Europe either as authors or co-authors. The very first to speak will be Dr. C. G. Keel whose paper has been scheduled for presentation on the afternoon of April 17th. Dr. Keel is director of the Swiss Welding Association; his co-authors are Dr. J. Colbus of West Germany and Dr. G. M. A. Blanc of Switzerland. All three are authorities on brazing.

The speaker who will follow Dr. Keel on April 17th, is Dr. L.

Wolff of Gesellschaft Für Linde's Eimaschinem, Munich, West Germany; his co-author is M. M. Komers who is also from West Germany where he is with Phoenix Rheinrohr A.G. in Düsseldorf. Both are experts in the field of gas-shielded arc welding. The third IIW speaker for the morning of April 17th is from Sweden. He is Evert Bylin, who is technical secretary of the Welding Commission of the Royal Swedish Academy of Engineering Sciences.

The second technical session sponsored by the International Institute of Welding has been scheduled for the morning of April 19th; a third and final session follows that afternoon. The first IIW author to speak on this day will be M. R. Cazaud of the Institut de Soudure in Paris, France. He will be followed in succession by Professor A. Van Douwen, dean of the faculty at Technological University of Delft in the Netherlands, and by Dr. W. B. Carlson, who is chief research engineer for Babcock & Wilcox, Ltd., in London, England.

All three IIW authors, who are scheduled to speak on the afternoon of April 19th, are eminently qualified in different phases of weldability. The three in the order in which they will appear are: Dr. N. Christensen, chief metallurgist and associate professor for the Engineering Research Foundation at the Technical University of Norway in Trondheim; Dr. A. A. Wells, assistant director for the British Welding Research Association in Cambridge, England; and Professor G. A. Homes from Brussels, Belgium.

Their Papers

In "Notes on the Appreciation of Brazing Filler Metals and Fluxes," Drs. Keel, Colbus and Blanc present data concerning the surface tension characteristics of molten filler metals and fluxes. The results of an original investigation are also presented concerning the relation between flux viscosity and the wettability of brazing filler metals underneath molten fluxes.

"Gas Mixtures in Shielded-Arc Welding with Consumable Electrode," by M. M. Komers and Dr. Wolff together with "The Solutions Adopted in Some Difficult Applications of Flash Welding," by E. Bylin of Sweden, deal with two timely subjects. The second of these two papers is concerned with the flash welding of cast iron in the joining of flanges to centrifugal-cast pipes wherein the flash welding of cast iron is shown to be possible, provided there is accurate control of the upsetting stroke in connection with very low specific upsetting pressure.

M. Cazaud subjects a welded assembly to a sequence of step increasing loads in his "Evaluation of the Fatigue Limit Using Only One Welded Specimen or Welded Assembly." With cumulative damage defined as n/N, the fatigue limit sought for can be computed geographically for $\Sigma\, n/N = 1$ according to Miner's hypothesis. An appropriate mathematical approach is also indicated in "The Calculation of Welded Connections," by Professor A. Van Douwen while, on the other hand, W. B. Carlson develops an approach to provide an adequate material bonus for good detail design in his "Pressure Vessel Design Requirements in the Future."

"The Role of Hydrogen in Arc Welding with Covered Electrodes," by Dr. Christensen considers the introduction of hydrogen into the weld puddle in terms of two main factors—the amount of potential hydrogen in the coating and the chemical conditions controlling the absorption of hydrogen. These are related to the temporary deterioration of the mechanical properties because of hydrogen and to permanent damage in the form of weld metal microfissures. The stated effect "Influence of Residual Stresses and Metallurgical Changes on Low-stress Brittle Fractures in Welded Steel Plates," by Dr. Wells is to bring together available information on welded and notched wide plate and pressure vessel tests where failure is induced by slowly applied loads, so that features are exposed relating to crack initiation and propagation together with the influence of some types of naturally occurring flaws. Professor Homes is author of the final paper of the nine sponsored by the IIW. No less than the others, it is a unique contribution to the understanding of specific problems which are confronted in welding.

AWS DIRECTORS-AT-LARGE

Term Expires	1961	1962	1963
	A. A. Holzbaur	Jay Bland	R. B. McCauley
	D. B. Howard	F. G. Singleton	John Mikulak
	J. L. York	C. B. Smith	E. F. Nippes
	W. H. Hobart Jr.	J. R. Stitt	R. D. Stout

AWS DISTRICT DIRECTORS

District No. 1•New England	G. W. Kirkley	District No. 6•Central	R. H. Hoefler
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		District No. 11•Northwest	C. B. Robinson

AWS PAST-PRESIDENT DIRECTORS

C. I. MacGuffie G. O. Hoglund

Welcome

•Sustaining Member

Effective Jan. 1, 1961:

Colorado Interstate Gas Co.
Colorado Springs, Colo.

This company, with headquarters in Colorado Springs, Colo., produces and transports natural gas. It started serving its primary market, the Rocky Mountain area (Denver, Pueblo, Colorado Springs), in 1928. Also, they provide gas supplies utilized in Chicago, Ill., and Amarillo, Tex., areas through facilities of other pipeline companies. Latest expansion plans call for delivery of natural gas to another pipeline company for use in Southern California. Subsidiaries include Natural Gas Producers, Inc., wholly-owned, and Colorado Oil Gas Corp., 57%-owned.

Sustaining Member Representatives—B. P. Schaberg and D. H. McCorkle.

KEEPING YOU POSTED

By Fred L. Plummer

● All 38 members of the AWS Headquarters Staff joined in a gay, informal luncheon party at the Sheraton-Atlantic Hotel on December 22nd to celebrate the end of another calendar year—one distinguished by outstanding performances of many of these individuals and by the effective service of all—and to mark the opening of our traditional year-end holiday season. Several important changes in personnel occurred during 1960, however a full staff of competent, devoted individuals were on duty at the start of the new year.

● On January 3rd your Secretary met with the Executive Secretaries of three of the founder engineering societies to discuss mutual problems, including some concerning the move to the new United Engineering Center which is now tentatively scheduled for August 1961. More than half of the 85 active AWS Sections have now fully met or exceeded their quota in the fund drive for this important project.

● The following day your Secretary traveled, together with Manager R. T. Kenworthy and A. L. Phillips, to Philadelphia to join members of the Exposition Committee in a meeting at the Engineers Club called by Chairman J. E. Norcross to finalize plans for the Welding Exposition to be held in the New York Coliseum April 18–20. Reservations of exhibit space, for which contracts have already been signed, indicate that all available space will be used and that again all records for total exhibit space and for total attendance will be exceeded.

● During the afternoon your Secretary met with President R. D. Thomas, Jr. at the Arcos Corp. offices, to review plans, for the AWS Annual Meeting (April 17–21 in Hotel Commodore, New York), the Annual Assembly of the International Institute of Welding (opening April 10th in Hotel Sheraton-Atlantic, New York), as well as those for AWS Section visits and several special projects.

● On January 9th Chairman J. E. Dato presided at a meeting in your Secretary's office of 15 of the men who are serving as leaders in completing arrangements for the combined AWS and IIW events which will bring to New York, during April, prominent engineers, scientists, educators, representatives of manufacturers, fabricators, government agencies and others interested in welding and allied processes. It is expected that representatives of all important industrial nations will attend and participate in the Commission, Board, Council and Committee meetings; the many technical sessions which will include 15 or more papers by representatives of foreign countries; the Welding Exposition; plant tours; receptions, dinners, luncheons, breakfasts and special events; and an interesting program for the ladies, covering the period April 12–20. These men in charge of arrangements include the Chairmen and other officers and members of the Long Island, New Jersey and New York AWS Sections.

● Following this meeting Chairman R. V. Thornton and J. W. Flannery of the New Jersey Section presented your Secretary with a check for $1460 payable to the UEC Building Fund. This amount represented the final payment of the full $2600 quota for this Section.

● During the evening of this day New York Section Chairman M. D. Bellware introduced Dr. Warren Savage of Rensselaer Polytechnic Institute who discussed his "Constitutional-Liquidation Hypothesis" before a joint meeting of AWS and ASM members. Staff Members Farrell and Orrok joined your Secretary as representatives of headquarters at this interesting and well-attended meeting.

● President and Mrs. Thomas spent this same day in Minneapolis as guests of AWS Section members and their wives. At a dinner meeting of the Section, President Thomas outlined Society Activities and then discussed "Some Dramatic Applications of Stainless and Low-alloy Steel Welding."

● In spite of a strike which prevented operation of Northwest Airlines flights, President and Mrs. Thomas continued to the West Coast for a meeting of the Portland, Ore., Section on January 10th at which President Thomas discussed "Electroslag Welding for Heavy Fabrication," and a meeting on January 12th with the Puget Sound Section at Seattle, Wash., at which he presented an Adams Memorial Membership to Professor Gilbert S. Schaller and discussed "Factors Affecting the Properties of Stainless Weld Metal." Mr. and Mrs. Thomas then enjoyed a short vacation at one of the more important ski resorts before joining your Secretary at a meeting of the Toledo Section, on January 18th.

● In New York on January 10th Past-president C. I. MacGuffie lunched with your Secretary and F. J. Mooney following a conference concerning industry support of and participation in the Annual Assembly of the International Institute of Welding. Visitors at headquarters the following day included H. F. Crick, welding engineer of Mosher Steel Co. in Houston, and H. T. Borton, president of Osborn Engineering Co. of Cleveland.

● Your Secretary attended a meeting of the important WRC Interpretive Reports Committee on January 12th. Past-president J. J. Chyle and Vice-president C. E. Jackson also attended this meeting held in the office of WRC Director Ken Koopman and his associate C. F. Larson with Chairman Jerry Claussen presiding as committee members considered subjects and possible authors for new reports.

● Following an early evening flight your Secretary was met at the recently-opened Montreal Air Terminal by CWS Past-president C. Sebistianowich and driven to the new Queen Elizabeth Hotel where speakers and chairmen gathered for breakfast the next morning before proceeding to École Polytechnique for an all-day seminar on codes and specifications and their effects on welding design. Principal speakers included R. S. Eadie, president of Canadian Standards Association; R. M. Gooderham, director of Canadian Welding Bureau; your Secretary; LaMotte Grover of Air Reduction Co.; A. M. Bair of Dominion Bridge Co.; and H. Thomasson of Canadian Westinghouse Co.

● This was the second annual seminar planned by officers of the CWS, Montreal Chapter. Session chairmen included N. Rehder, F Schneider, C. Sebistianowich, J. Hamel, D. F. Eckkeli and J. Taylor. Other members in charge of plans for this very successful seminar were G. F. W. Barrett, W. D. Hyde, Andre Hone, L. E. Baxter, G. Cape and H. H. Yates.

● Plans to return to New York early the following Saturday morning were disrupted by a massive fog which blanketed the New York area, delayed take-off at Montreal for several hours, necessitated a holding pattern in the air over Idlewild Airport and finally permitted landing during mid-afternoon.

● Early departures on January 17th of Vice-president C. E. Jackson from Newark and your Secretary from LaGuardia Airport made possible a meeting in Washington, D. C., and a continuing morning flight via Charlottesville, Lynchburg and Roanoke to Tri-Cities Airport serving Kingsport, Johnson City and Bristol (on the Virginia-Tennessee state line) where Holston Valley Section officers Larry Long, Jim Meyers, Bob Lahr and visitor J. W. Clark extended a most cordial welcome and were hosts for a late lunch at a restaurant in Johnson City. This was followed by a most interesting tour and inspection of the varied and extensive welding facilities of the huge plant of Tennessee Eastman Corp. located in this city. In addition to Long and Meyers, A. D. Caley and Bill French helped make this visit a truly memorable occasion.

● A short auto ride to Bristol provided an opportunity to check in and freshen up at a new Holiday Inn before the social hour, steak dinner and meeting of the Holston Valley Section at Trayer's Restaurant on the Virginia side of the Va-Tenn line. Chairman C. W. Griffith conducted the meeting with the assistance of officers Hackley, Harr, Rogers, Scott, Snuggs and Tadd in addition to those previously named. Past-chairman R. W. Lahr presented your Secretary with a check payable to the UEC Building Fund and increasing the total payments for this Section to 109% of its quota. Following a short description of Society activities by your Secretary, Vice-president Jackson discussed "The Science of Arc Welding" using several of the fine illustrations prepared for his Adams Lecture dealing with this same subject.

● Vice-president Jackson stayed in Tennessee for a lecture given before the Northeast Tennessee Section at Oak Ridge on January 19th. Your Secretary was guest of L. M. Long at a 6:30 breakfast followed by a ride to the Tri-Cities Airport for departure on a series of flights with many stops including Cincinnati and Chicago where he was joined by President and Mrs. Thomas for the final flight to Toledo, Ohio, on January 18th. Toledo Section Chairman J. L. Barker and Vice-chairman Ben Schlatter were waiting at the airport to provide transportation to downtown Toledo and later to the Toledo Yacht Club for the dinner meeting of the Section. Director Ray Stitt, Past-director Keith Sheran, Past-chairman Gordon Kirkwood and Vice-chairman R. Zacharie headed a 19 member group representing the Detroit Section at this well-attended meeting. Representatives of the North Central Ohio Section were also in attendance.

● District Director R. H. Hoefler, President Thomas and your Secretary were "Coffee Hour" speakers at the dinner prior to the technical meeting at which Phillip L. Sommer of the LeTourneau-Westinghouse Co. discussed "Time Study for Welding" and described the very effective and unusually comprehensive procedures developed by large users of welded fabrications. Section officers in addition to Barker and Schlatter, participating in this event included Baughman, Braithwaite, Brown, Ellis, Lorenzen, Stryz, Waterbury, Weide, Wohlmuth and Wolcott.

● On this day Asst. Secretary Frank J. Mooney started a trip which took him to Roanoke, Charlotte, Atlanta, Huntsville, Memphis to meet with individuals interested in organizing AWS Sections, and to Chicago and Milwaukee to complete preliminary arrangements for national meetings scheduled for these cities. Mr. Mooney is now devoting a major portion of his time to direct membership activities.

● Switching to a train as a result of a major plane delay due to equipment trouble, President and Mrs. Thomas and your Secretary proceeded to South Bend, Ind., on January 19th for a meeting of the Michiana Section. An interest-

ACRO WELDER MFG. CO.
MILWAUKEE
WELDING ENGINEERS
MACHINERY BUILDERS
ESTABLISHED 1936

ACRO® general purpose spot-projection-butt-seam resistance welding machines.

ACRO-ARC® special purpose production welding machinery employing automatic arc welding processes.

ACROMATIC® special purpose production welding machinery employing resistance welding processes.

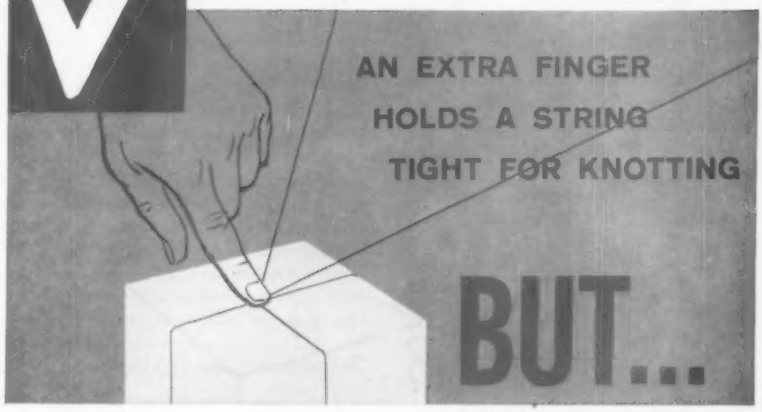
ACRO-MAGNETIC® magnetic force spot, projection, and percussion welding machines.

For details, circle No. 8 on Reader Information Card

ing afternoon with Section Secretary W. G. Fassnacht at Bendix Products was followed by the dinner meeting at Russ' Restaurant with Chairman Robert Bauss, Vice-chairman Floyd Doolittle and Treasurer Leo Cuthbert directing activities. President Thomas described dramatic applications of stainless and low-alloy steels after your Secretary discussed local and national educational activities, the new United Engineering Center and plans for the AWS Annual Meeting and Welding Exposition and the IIW Annual Assembly to be held in New York next April.

● President Thomas spent the following day with business associates while Mrs. Thomas and your Secretary traveled to Chicago by train, joining President-elect A. F. Chouinard (confirmed by report of Tellers of Election on January 30th), Section Chairman L. C. Monroe and their wives for lunch at the Illinois Athletic Club. Mrs. Thomas enjoyed a tour of Chicago as guest of Mrs. Chouinard during the afternoon and was dinner guest of Mrs. Monroe together with Mrs. Chouinard, Mrs. McPhee and Mrs. Meyer. Your Secretary and Mr. Chouinard discussed committee appointments and plans for the fiscal year beginning June 1, 1961, and then joined Chairman Monroe, President Thomas and members of the Chicago Section Executive Committee for a late afternoon meeting which was followed by a social period and dinner at Milner's Restaurant. At the technical meeting in the auditorium of the Peoples Gas Light and Coke Co., President Thomas discussed both electroslag and electrogas welding of plates varying from very great thicknesses down to as little as three-eighths of an inch. Your Secretary described specific Society projects and both President Thomas and Chairman Monroe presented certificates (national and section) to Mr. Homer Gannett honoring his long time membership in the Society. Mr. Gannett responded graciously and presented a generous check to the UEC Building Fund. Mr. Chouinard assisted Chairman Monroe in conducting the meeting in which many active and well-known members and officers of the Section participated. These included Vice-chairman R. C. Becker, Secretary E. P. Gruca, H. C. Close, R. A. Hynes, T. B. Jefferson, A. P. Bunk, I. H. Carlson, A. G. Craske, L. McPhee, A. Meyer and a long list of equally prominent AWS personalities.

IT'S A FACT



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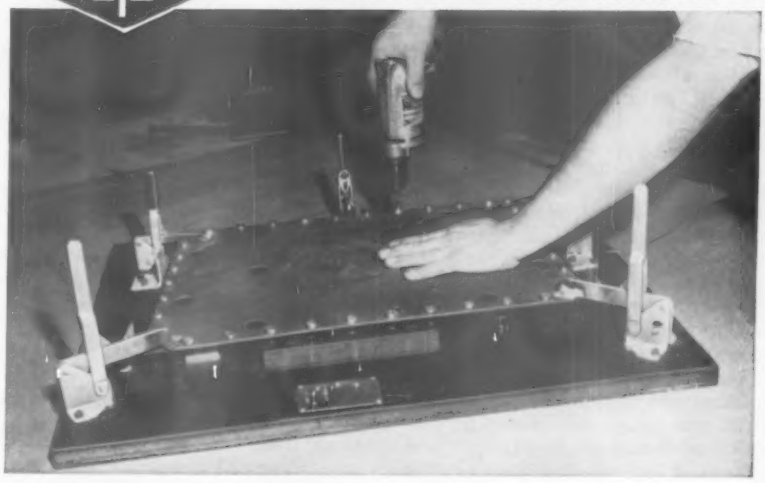

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EDUCATIONAL ACTIVITIES

Welding Handbook

Section 4 of the WELDING HANDBOOK is now available and distribution to AMERICAN WELDING SOCIETY members should be completed by the end of March.

Containing 550 pages, the new section has 17 chapters and covers metals and their weldability. This is going to be one of the most valuable sections of the WELDING HANDBOOK since it gives the very latest information on the various metals, a brief description of the metallurgical factors involved and the latest techniques in welding.

New chapters have been added, such as "Titanium and Titanium Alloys," "Precious Metals" and "Filler Metals."

The chapter on "Titanium and Titanium Alloys" is particularly important since it contains information on welding these metals which has never before been published. This information will be invaluable to all who work with these most useful metals.

It is difficult to overestimate the value of the "Filler Metals" chapter. This is the first time an AWS Handbook has ever had a comprehensive chapter on filler metals. The Third Edition carried a chapter on "Filler Metal Specifications," but this told only half the story. The new chapter has been compiled by the top people in the field and contains information on filler metals which will make this section a must wherever welding is done.

It is surprising how much new information is available on the old standbys iron and steel, to say nothing of the stainless steels and nickels, which are of ever-increasing importance. These chapters have been revised and brought up to date.

In the light metals, aluminum and magnesium, there have been tremendous strides made during the last 10 years. Consequently these chapters, particularly "Aluminum and Aluminum Alloys," have been enlarged beyond recognition. Technical experts who have reviewed the copy in galley form are unanimous in acclaiming these chapters as a distinct contribution to welding.

Many companies have expressed a desire for reprints of the various chapters. These reprints are usually bound in an inexpensive paper binding and are available at a price which permits wide distribution. In this booklet form, the material can reach a much wider public than in the WELDING HANDBOOK which is too expensive for companies to distribute indiscriminately.

Any company interested in obtaining reprints of these chapters should get in touch with the AWS Information Center because the cost of these reprints depends upon the size of the print order.

National Welded Products Month

The new Planning Manual for National Welded Products Month has proved very helpful to Sections. Many of the suggestions made in the manual have been adopted by the Sections. The publicity chairmen are finding the specimen proclamation very useful. Many of the Sections are now writing news releases, patterned on the specimens contained in the manual.

Sections are working very hard at this promotion, and we predict that this April will hit a new high in welding publicity.

It has been found that local chambers of commerce are exceedingly interested in this project. Department stores and the like are hard put to find a gimmick on which to hang their various promotions. Year after year they use the same theme, and it has been reported that they eagerly pounce upon National Welded Products Month as an excellent means to promote store publicity. The store managers realize that participating is very easy. All they have to do is to fill their window with practically any fabricated metal products, such as appliances, mark them "Welded Products," add a "THIS IS NATIONAL WELDED PRODUCTS MONTH" sign, and the promotion is made for them. They can tie it in with the National Meeting and Welding Exposition; and, since there is such a variety of projects from appliances to "what the well-dressed welder will wear this year," practically every type of store can join the bandwagon.

One suggestion that was made in New York was that a very well-known Fifth Avenue ladies' department store interest their clients in the promotion by means of welded sculpture. This might be a useful suggestion for other areas where sculptors in welding can be found.

Check List for NWPM Projects

A check list has been sent out to all section publicity chairmen, asking them to check off the areas in which their committees plan to work. The list includes these various areas:

- Form National Welded Products Month Committee Sub-Committees, Task Forces
- Mayor's Proclamation
- Governor's Proclamation (cooperate with other Sections in your state)
- News Releases
- Plant Tours
- Open Houses
- Provide Luncheon and Dinner Speakers
- Store Window Promotion
- Welded Products Displays
- Use of AWS Emblems
- Postage Meter Slug
- Mention National Welded Products Month in Radio and TV Commercials
- Mention National Welded Products Month in Advertising Copy
- Imprint National Welded Products Month on the Foot of Letterheads
- Prepare Copy for House Organs and Company Publications
- Use "Welded Product" Sticker on Everything Welded

It is of vital importance that national headquarters receives photographs, press clippings, proclamations and other publicity items in order that they may be reproduced to tell the world what each Section is doing.

1961 Welding Show

Next month thousands of our members will be meeting in New York to hear the technical papers read and visit the Welding Show where they will see the latest developments in equipment, materials and processes. This is also the year when we are host to the International Institute of Welding and to delegations from 27 countries visiting us. There is probably more to be gained in the five-day meeting and Welding Show than in the whole of the year.

SECTION NEWS AND EVENTS

As reported to Catherine M. O'Leary

Alabama

HARD SURFACING ALLOYS

Birmingham—The January meeting of the 1960–61 season of the *Birmingham* Section was held at Salem's Restaurant Number Two on Tuesday, January 10th.

Albert J. Zvanut, sales metallurgist, Stoody Co., was guest speaker. He presented a fine talk on "Manufacture, Metallurgy, Processes and Applications of Hard-facing Alloys." He pointed out the difficulties that exist in the proper selection of hard-facing alloys and what the AMERICAN WELDING SOCIETY is doing to counteract this problem.

After this presentation, a discussion was held on the various applications involving semiautomatic and fully-automatic processes, well supported with slides.

HIGH STRENGTH STEELS

Mobile—Thirty-two members and guests were present for the dinner meeting held on Dec. 13, 1960, by the *Mobile* Section at Korbet's Restaurant.

A panel discussion on the "Welding of High Yield Strength Steels" was held. James M. Shilstone, Director of District No. 4 and of Shilstone Testing Laboratories in Baton Rouge, La., was the panel moderator and guest speaker. Panel members were: E. H. Holder, Ingalls Shipbuilding Co., Pascagoula, Miss.; J. D. Smith, Alabama Dry Dock & Shipbuilding Co., Mobile; and Leo Veal, Rowell Welding, Inc., Mobile.

Mr. Shilstone opened the panel discussion by giving a brief history of the steels, the extent of their usage, the future usage, and what is gained by using T-1 steel vs. mild steel.

It was pointed out that, because of its quenched and tempered characteristics, T-1 steel has a yield strength nearly three times that of mild steel. Although T-1 steel is presently being used in pipe systems, bridges, ships, submarines, heavy construction machinery and many other products, it has many desirable characteristics for plant maintenance. Its high yield strength allows a great reduction in size and weight of members when replacing mild steel. T-1 steel also has desirable abrasion and corrosion resistance that enhances its use for industrial trouble areas. Preheating of the steels requires stringent control with different temperatures for various thicknesses with the maximum of 300° F. Interpass-temperature control plays an important part in successful welding and is the major factor governing the welding sequence to be used.

Mr. Holder emphasized the common problems of welding T-1 and HY-80 steels, while Mr. Shilstone discussed the "Comparative Test Results of Low Hydrogen vs. E60-10 Welds." Mr. Shilstone guided the panel with questions from himself and the audience and maintained an attentive and responsive group.

California

WELD FAILURE

Sunnyvale—A panel discussion on "Causes of Weld Failure" was conducted by Lon Mayr of Westinghouse for the *Santa Clara Valley* Section on December 27th at Sabell's in Sunnyvale.

Those who participated were the Messrs. E. Hazlett of the University of California, Berkeley; A. D. Hubbard, General Electric Co., San Jose; Fortune Masedo, Heller Aircraft, Palo Alto; Ray Townsend, Tweco Products, Los Gatos; and R. H. Rhoades, Sylvania, Palo Alto.

Some of the items covered were (1) foreign inclusions in the deposited weld bead in relation to its action as a corrosion activator, a stress riser and the maximum allowable amount of material concentration and relative location in the weld deposit; (2) weld bead undercut in relation to base material, joint design and application of the weldment; (3) improper or poor selection of base material and/or loose material specifications requirements; (4) material transition phase temperature failures, and (5) the use of inadequate or inefficient welding equipment and welding accessories.

During the meeting, Section Chairman W. R. Smith presented "Certificates of Commendation" to the following past chairmen: M. M. Griffith (1954–55), W. J. Erichsen (1955–56), Fortune Masedo (1956–57), M. J. Sebastian (1957–58), A. M. Hubbard (1958–59) and R.N. Skow (1959–60).

WELD FAILURE PANEL

Panel members discuss "Weld Failure Causes" at December 27th meeting of Santa Clara Valley Section. Left to right are: Dr. E. Hazlett, L. Mayr, A. D. Hubbard, R. H. Rhoades and R. Townsend

Colorado

FLAME FLUXING

Denver—The December meeting of the *Colorado* Section was held at Cavaleri's Restaurant in Denver on Dec. 13, 1960. The group gathered at about 6:30 P.M. for an appetizer until 7:00 P.M. when dinner was served.

Harry Pecor, who is publicity manager for All-State Welding Alloys Co., was main speaker for the evening. His topic was "The Use of Automatic Flame Fluxing with Oxyacetylene, Oxy-propane, City and Natural Gas." His talk was augmented with slides showing applications of automatic-flame fluxing.

The coffee speaker, Jack Gossman of United Air Lines, presented an insight into the operations and unusual problems of the airline business.

SECTION MEETING CALENDAR

MARCH 24

WESTERN MICHIGAN Section. Grand Rapids, Mich. "Power Sources."

MARCH 28

SANTA CLARA VALLEY Section. Sabella's Restaurant "Ebb Tide Room," Sunnyvale, Calif. 7:00 P.M. "New Techniques in the Field of Welding," Harry Schwartzbart, Armour Research Foundation.

APRIL 3

LEHIGH VALLEY Section. Demonstration Night. Lafayette College, Easton, Pa.

OKLAHOMA CITY Section. Cattleman's Cafe. Dinner 6:30. Meeting 7:30. "Brazing for High-temperature Service," R. L. Peaslee, Wall Colmonoy Corp.

APRIL 4

TULSA Section. Plant Tour. Muskogee, Okla.

APRIL 5

SUSQUEHANNA VALLEY Section. Foot Hills Manor, Shickshinny, Pa. "Arc Characteristics of Gas-Shielded-Arc Welding," G. R. Rothschild, Air Reduction Co.

APRIL 6

NORTH CENTRAL OHIO Section. To be announced.

NORTHERN NEW YORK Section. Stanley Club, Pittsfield, Mass. "It Isn't Mud" (Electrode Coatings), Harry F. Reid, McKay Co.

SAGINAW VALLEY Section. Saginaw, Mich. "Monautronic Welding Controls," B. L. Mack, The Budd Co.

APRIL 10

BOSTON Section. Hotel Bostonian, Boston, Mass. "Welding Missiles," W. A. Wilson, Redstone Arsenal.

NORTHWEST Section. Minneapolis, Minn. "Modern Methods of Metal Removal," Myron Stepath, Arc Air Co.

APRIL 11

BIRMINGHAM Section. "Oxygen Cutting Processes," J. F. Kiernan, Airco.

DAYTON Section. Kuntz's Cafe, Social 6:30. Dinner 7:00. Meeting 8:00. "Selection of Best Arc Welding Method for Stainless and Low-alloy Steels," Wayne L. Wilcox, Arcos Corp.

SANGAMON VALLEY Section. Springfield, Ill. "The Integrated Welding Line," F. A. Bodenheim, Federal Machine & Welder Co.

APRIL 13

ALBUQUERQUE Section. 7:30 P.M.

IOWA-ILLINOIS Section. Highland Park Bowl, Moline, Ill. Dinner 6:30. Meeting 7:30. "Tools for Mechanized and Automatic Welding."

J. A. K. Section. Aurora, Ill. "Resistance Welding."

ST. LOUIS Section. Ruggeri's Restaurant. "Fabrication of High-strength Steels as Applied to Submarine Vessels," E. H. Franks, Electric Boat Div., General Dynamics Corp.

APRIL 14

COLUMBUS Section. Plant Tour.

APRIL 17

HOUSTON Section. (Corpus Christi Division). "Welding Inspection," Sam Bryan, Shilstone Testing Lab.

PHILADELPHIA Section. Engineers Club. 8:00 P.M. "Methods Engineering as Applied to Welding."

APRIL 18

MOBILE Section. Korbet's Restaurant. Social hour 6:30. Dinner 7:15. Technical Session 8:00.

NORTHWESTERN PENNSYLVANIA Section. Erie, Pa. "Automatic Welding."

OLEAN-BRADFORD Section. Plant visit of Clark Bros. Co., Turbo Products Div.

APRIL 19

FOX VALLEY Section. Appleton Elks Club, Appleton, Wis. 7:30 P.M.

HOUSTON Section. "Power Sources for Arc Welding," Emil F. Steinert, Westinghouse Electric Corp.

PEORIA Section. Vonachen's Junction. Dinner 6:30. Meeting 8:30. "Metallurgy of Ferrous Welding," Gordon E. Grotke, U. S. Steel Research.

TOLEDO Section. Toledo Yacht Club. Dinner 6:30. Meeting 7:45. Maintenance Welding Panel.

APRIL 20

BATON ROUGE Section. Election of Officers. "Welding of Nickel and High-nickel Alloys," Kenneth M. Spicer, International Nickel Co. Inc.

BEAUMONT Section. "Power Sources for Arc Welding," Emil F. Steinert, Westinghouse Electric Corp.

IOWA Section. "Fasteners for Resistance Welding," Gregory F. Grey, Ohio Nut & Bolt Co.

MADISON Section. Beloit, Wis.

MAHONING VALLEY Section. Victoria Restaurant, Youngstown, Ohio. Dinner 7:00. Meeting 8:00. Plant Visitation.

MICHIANA Section. South Bend, Ind. Ladies' Night.

APRIL 21

MARYLAND Section. Engineers Club, Baltimore. Dinner 6:30. Meeting 8:00. Battle of the Sections: York, Susquehanna Valley, Lehigh Valley, Philadelphia and Maryland.

APRIL 24

WESTERN MICHIGAN Section. Grand Rapids, Mich. Talk on Time and Motion.

APRIL 27

NIAGARA FRONTIER Section. LaSalle Yacht Club, Niagara Falls, N. Y. Panel Discussion—Olean-Bradford, Northwestern Pennsylvania and Niagara Frontier Sections.

APRIL 28

HOUSTON Section (Austin Division). Villa Capri Restaurant. Social period 6:30. Dinner 7:00. Program 8:00. "General Metallurgy," Ed Hildebrand, Humble Oil & Refining Co.

INDIANA Section. Plant tour of Delco Radio at Kokomo, Ind.

MILWAUKEE Section. Ambassador Hotel. Buffet dinner 6:30. Meeting 8:00. "Factors Affecting the Properties of Stainless Weld Metals," R. D. Thomas, Jr., Arcos Corp. "AWS Activities," F. L. Plummer, National Secretary.

Editor's Note: Notices for June 1961 meetings must reach the JOURNAL office prior to March 20th, so that they may be published in the May Calendar. Give full information concerning time, place, topic and speaker for each meeting.

STAINLESS STEEL

Denver—The January 10th meeting of the *Colorado* Section was held at Cavaleri's Restaurant in Denver. The group gathered at about 6:30 P.M. for an appetizer until 7:00 P.M. when dinner was served.

J. A. Goodford, chief welding engineer of the Crucible Steel Co., was the main speaker for the evening. His topic was "General Welding and Fabrication of Stainless Steel." He discussed different types of electrodes, proper and improper joint designs and the use of various welding processes, and many other problems that arise while fabricating and welding stainless steels. His talk was augmented with a number of very interesting slides.

Coffee speaker was T. E. Jaramillo, chief revenue agent of the Colorado State Income Tax Department. He spoke on the new tax laws that can be expected for the coming year.

Florida

ECONOMICS

Hialeah—On Dec. 21, 1960, the *South Florida* Section held its regular monthly meeting at the Park Lane Cafeteria in Hialeah.

Those who took the time off from a busy holiday season heard one of the finest guest speakers that the Section has presented during the year.

Guest speaker for the evening was Richard J. Welsch, director of Dade Country Development Department, Miami. His subject was "Economic Future of Metropolitan Miami."

Mr. Welsch's program was indeed very interesting and well received. Due to the small turnout at this season of the year and the importance of Mr. Welsch's program, it was suggested that he be invited to present his program again at a future meeting.

Illinois

CHRISTMAS DINNER

Joliet—The first annual Christmas dinner of the *J. A. K.* Section was held on December 15th at Bill Meade's Cozy Cottage on Route 66A north of Joliet. Forty members and their ladies enjoyed a fine prime rib dinner. An enjoyable performance was given by Jim Waltz, mimic. Gifts were

1961 WELDING SHOW...

A market place of welding where new and improved products will be on display—a meeting place for old and new friends—an information exchange center for those with an interest in welding and metal fabrication . . .

New York Coliseum—
Home of 1961 AWS
Welding Exposition

42ND ANNUAL MEETING AND EXPOSITION

APRIL 17-21

APRIL 18-20

APRIL IS NATIONAL WELDED PRODUCTS MONTH

Ship Building

Construction Industry

Heavy Manufacturing

THE WELDING SHOW

IS THE SHOP WINDOW FOR WELDING MATERIALS AND EQUIPMENT, AND REPRESENTS YOUR GREATEST OPPORTUNITY DURING 1961 TO SEE NEW PROCESSES AND EQUIPMENT

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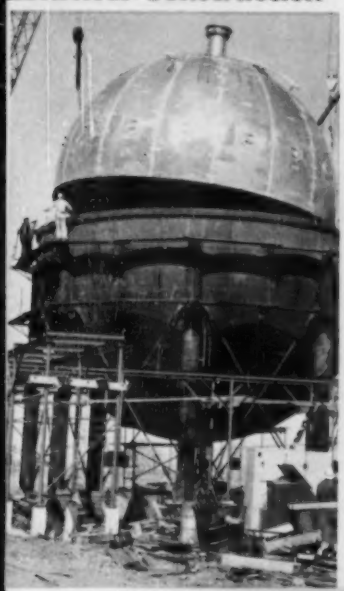
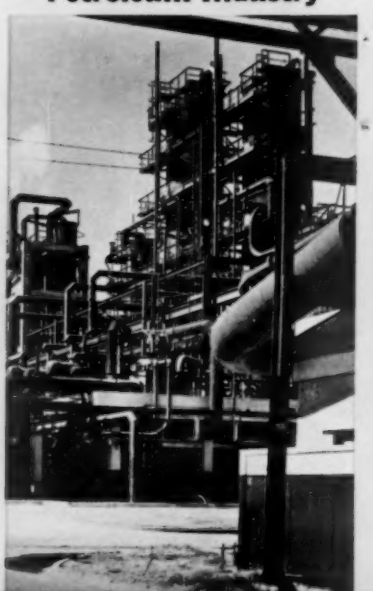
Nuclear Construction



Aircraft Industry

Petroleum Industry



THE BILLION DOLLAR WELDING INDUSTRY

AMERICAN WELDING SOCIETY

WELDING SHOW

NEW YORK IS EXPECTED TO DRAW THE LARGEST ATTENDANCE EVER RECORDED IN THE HISTORY OF THE WELDING SHOW

COLISEUM NEW YORK APRIL 18-20, 1961

Each exhibitor represents the "Who's Who" for a billion dollar industry embracing all types of welding. This is your chance to approach him for answers to questions you have concerning:

Air-acetylene
Arc-seam
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Bare metal-arc
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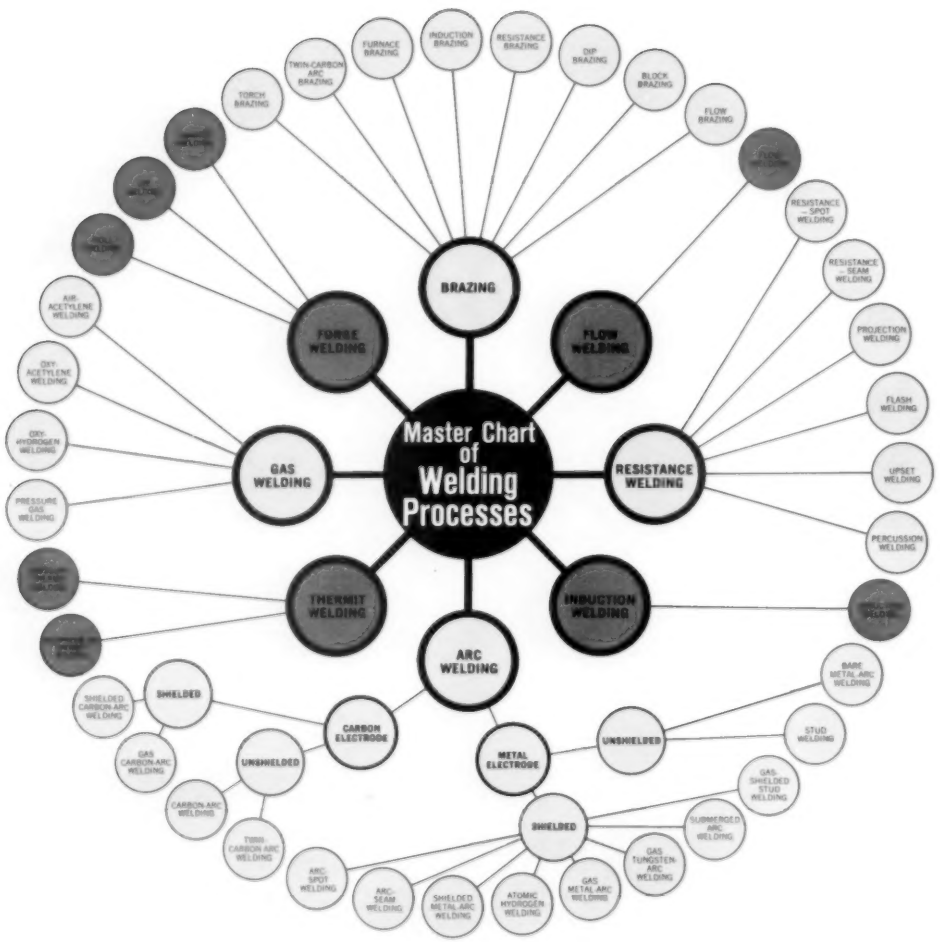
Carbon-arc
Die welding
Dip brazing
Flash welding
Flow brazing
Flow welding
Furnace brazing
Gas carbon-arc
Gas metal-arc
Gas-shielded stud
Gas tungsten-arc
Hammer welding
Induction brazing
Induction welding
Nonpressure thermit
Oxyacetylene
Oxyhydrogen
Percussion welding
Pressure gas
Pressure thermit
Resistance brazing
Resistance seam
Resistance spot
Roll welding
Shielded carbon-arc
Shielded metal-arc
Stud welding
Submerged arc
Twin-carbon arc brazing
Twin-carbon arc welding
Upset welding



NOTE: The Master Chart of Welding Processes has been revised to include new material and is available in full Multi-color. For information on how to obtain either wall or desk size charts, write to **Dept. T, American Welding Society, 33 West 39th St., New York 18, N. Y.**

SPEAKER IS GREETED

A. F. Boucher (center) of the Lincoln Electric Co. before he spoke at Peoria Section meeting on November 18th. Section Chairman H. Smith is at left, and technical chairman G. Svihla is at right

raffled off for the ladies. A corsage was given to each lady. A fine time was had by all.

WELDING DEVELOPMENTS

Peoria—On Nov. 16, 1960, the *Peoria* Section held its regular monthly dinner meeting at Vonachen's Junction at 6:30 P.M. Guest speaker was A. F. Boucher, assistant general sales manager of the Lincoln Electric Co.

Mr. Boucher gave an interesting talk on the latest developments of automatic and semiautomatic welding which was enthusiastically received by the large audience in attendance.

Indiana

PLANT TOUR

Shelbyville — Highlight of the December meeting of the *Indiana* Section was a plant tour of the General Electric Industrial Heating Department at Shelbyville. The tour took place on December 16th.

The group enjoyed a fine dinner at the Chicken and Steak Restaurant in Shelbyville. Following dinner and short business meeting, Bob Evans of General Electric welcomed the group and gave a brief description of the plant and its products.

Major manufacturing activities at the plant include the fabrication of industrial type heating equipment or heavy fabrication and the manufacture of small heating components such as cal-rod units, surface heaters, soldering irons and appliance elements. Specialized process equipment requiring specialized heating facilities is also designed and fabricated. Most of the weldment fabrication observed was carried out on furnace chambers and gas atmosphere equipment and utilized E6011 or the iron-powder stick electrodes, with a great amount of in-position welding. The manufacture of the small devices, and especially the applicance heating elements, attracted the group's interest.

Kansas

FLUX-CORED WELDING

Wichita—The *Wichita* Section held its first meeting of 1961 on January 9th at the University of Wichita Shocker Room in the Student Activity Center Building.

Following a most enjoyable dinner, prepared by the student chefs, the 33 people in attendance enjoyed a semitechnical presentation on "A Progress Report on the Fluxed Cored CO_2 Welding Process—Dual Shield." This "Progress Report" was very ably presented by J. A. Howery, of the Research and Development Department, National Cylinder Gas Co., Chicago, Ill.

The flux-cored process was completely described, along with applications and uses. Charts were shown on slides giving the physical properties of the various wires. Movies described actual customer company applications of the welding process. A question-and-answer period followed this most interesting presentation.

PAST CHAIRMAN'S NIGHT

Wichita—The *Wichita* Section held its monthly meeting at the Stockyards Hotel on Dec. 12, 1960. Past Chairman's night was observed and 14 past chairmen were honored with special presentations.

The group also enjoyed the showing of two films by the Chicago Bridge & Iron Co. R. L. Blandford, construction engineer from Tulsa, Okla., acted as narrator for the two films, which were shown as follows: (1) "Dresden Sphere Atomic Reactor Power Station." (2) "An American Landmark"—a 1,500,000-gal. elevated steel water storage tank constructed at Wheaton, Ill.

Louisiana

COVERED ELECTRODES

Baton Rouge — H. F. Reid, manager, Technical Service Division of the McKay Co., York, Pa., gave a talk on "Progress in the Development of Coated Electrodes" at the Dec. 15, 1960, meeting of the *Baton Rouge* Section held at the Sherwood Forest Country Club.

Mr. Reid discussed the historical treatment of the development of coated electrodes, primarily since World War II. The current trends were emphasized and prospects for the near future, along with research findings. Mr. Reid, a dynamic speaker, made his second appearance in Baton Rouge at the request of the Section members.

Maryland

PAST CHAIRMAN'S NIGHT

Baltimore—The *Maryland* Section held their regular monthly meeting on November 18th at the Engineers Club in Baltimore.

Past Chairman's Night was the occasion and the Section was honored with the presence of National President R. D. Thomas, Jr., and National Secretary Fred Plummer. There were 15 of the 17 past chairmen present. Letters of regret were

COFFEE AND DESSERT FOR WICHITA

Scene just a few minutes before Wichita Section heard guest speaker J. A. Howery present informative talk at January meeting

DINNER INFORMALITY

National Secretary F. L. Plummer and President R. D. Thomas, Jr., enjoy conversation with Maryland Section members on November 18th

received from the other two.

Mr. Plummer spoke on the activities and plans of the SOCIETY. He also reported on the progress of the United Engineering Center in New York.

Mr. Thomas' talk dealt with various applications of stainless and low-alloy steels. He stressed the need for research and progress in welding to keep abreast of the needs of industry in this space age.

Massachusetts

POWDER TORCH BRAZING

Boston—Two experts in their respective fields provided an interesting and informative program for over one hundred members and guests of the *Boston* Section at a meeting held on January 9th at the Bostonian Hotel.

Dick Jones of the Medium Steam Turbine Department of General Electric Co., Lynn, Mass., and a member of the Boston Section, gave a coffee talk on "Building Your Dream Boat." His latest of seven do-it-yourself boats constructed in his spare time is the "Jolly Roger." Colored slides provided minute detail of the planning and building of an original broad beam design suitable for carrying six passengers and towing water skiers on New England's lakes. Results of the over 500 hr of labor were clearly evident in the movies of the boat in action.

TWO EVENINGS IN WORCESTER

Guest speaker T. J. Moore (center) is shown after he was greeted by Worcester Section members on November 14th. Left to right are: K. Clarke, J. Belisle, T.J. Moore, Trade School guest J. St. Germain and J. Kelly

Dinner pause on January 9th when D. Holster of the Air Reduction Sales Co. was guest speaker

H. E. Miller, chief manufacturing engineer Coil Division of Carrier Corp., Syracuse, N. Y., and National Membership Chairman, described powder torch brazing with the aid of slides. The process involves brazing light-wall steel tubes with fine nickel-silicon-boron powder fed into an acetylene torch with special adapter.

Prior orthodox welding methods required a minimum of $^1/_8$-in. wall material to prevent burn-through. Leakage of ammonia through the joints of the refrigeration coils has been completely eliminated by the new technique.

Mr. Miller conducted a question-and-answer session at the conclusion of his talk and provided a number of sample joints made by this method for inspection by the audience.

CO_2 WELDING

Worcester—Dave Holster, application engineer with Air Reduction Sales Co., New York, N. Y., was the featured speaker at the January 9th dinner meeting of the *Worcester* Section held at Hickory House.

Mr. Holster held the audience's attention for 45 min with a very well presented discussion on where, why, and how CO_2 is used in welding today. In doing so, he touched on the shielding process of the arc and the transfer of metal across the arc.

A very active 30-min discussion period followed, which indicated that Mr. Holster had added much to this year's program.

ELECTROSLAG WELDING

Worcester—Thirty-three members and guests of the *Worcester* Section enjoyed a discussion on "Electroslag and Electrogas Welding" given by Thomas J. Moore of the Arcos Corp., at the November 14th dinner meeting held at Nick's Grille.

This is the first time that this section has had a speaker on this subject, and it is evident from the interest shown that this subject will be pursued further.

Mr. Moore covered the theory, process and some of the costs involved. It was also pointed out that the Russians have used the process for some time.

Michigan

EUROPEAN WELDING

Detroit — "European Welding

EUROPEAN SYMBOLS

Guest speaker C. R. Bates illustrating European resistance welding control-panel symbols at Detroit Section meeting on January 13th

Processes and Progress" were the topics covered by C. R. Bates, manager of Design Engineering of the Progressive Welder Co. of Canada, in a humorous, disk-jockey style discourse before the *Detroit* Section at their January 13th meeting.

Mr. Bates, who has traveled extensively and has visited most parts of the world in connection with resistance welding, recently undertook a survey of the market for resistance welders in every country in Europe. He drew freely from his experiences during this trip for his lecture. Among the many interesting items covered were: spot welding of structural steel, precision automatic welding machines by the Swiss, a miniature hand-size resistance welder to weld 0.0004-in. diam wire, Finland seam-welding at the rate of 90 ipm and flash-welding of railroad rails being used extensively in Europe and Africa.

EDUCATIONAL SERIES

Detroit — A four-phase educational series of welding courses is under way by the *Detroit* Section under the chairmanship of Professor Les Wagner of the University of Michigan. The series was planned to attract both the novice and the expert and to encourage everyone in the area to further their knowledge of welding.

The first phase, an eight-weeks course which is introductory in nature and which is now in progress at the University of Michigan Extension Building in Dearborn, Mich., is outlined as follows: February 13—Joining of Metals; February 20 and 27th—Resistance Welding; March 6th—Arc Welding; March 13th—Inert-gas Metal-arc Welding; March 20th—Gas Welding and Cutting; March 27th—Brazing; April 3rd—Metallurgy.

Tuition for this first series is set at $15 for AWS members and $30 for nonmembers. By paying an additional $5.00 initiation fee over and above the tuition, a nonmember becomes a member. Textbooks are included in the tuition. Certificates of completion are to be issued to all who attend at least 70% of the sessions.

The other phases of the series, each consist of eight lectures, are to be more intensive and specialized as follows: Second Series, Resistance Welding; Third Series, Arc and Inert-arc Welding; Fourth Series, Advanced Welding Metallurgy.

For further information contact Professor Les Wagner, University of Michigan, 3307 E. Engineering Bldg., Ann Arbor, Mich.

OXYACETYLENE PROCESSES

Saginaw—Over 80 members of the *Saginaw Valley* Section met on January 5th for dinner and meeting at the High Life Inn. Program speaker was E. Meincke, development manager of the Distributor Products Dept. of the Linde Co.

Mr. Meincke's talk on "Oxyacetylene Processes" covered many of the well-established oxyacetylene processes such as cutting, welding and hardening as well as considerations entering into the successful use of these processes. Slides were used to show burning torches and tips and their uses. Mr. Meincke is a fine speaker, and everyone enjoyed his talk very much.

At each meeting the Section has a raffle to raise money for the new United Engineering Center. This has been very successful so far.

Saginaw Valley Section Challenge on Meeting Attendance Contest

1. We will bet all of the active sections of the AWS that our attendance for the 1960–61 year will be better than theirs.

2. The wager would be for some local well-known food product with recipes for preparation. Your half of the wager should appear in the challenge acceptance letter.

3. The challenge, to be valid, must be accepted in writing by the section being challenged. If you are not interested, just ignore this.

4. The judges will be Fred Plummer, AWS secretary; Cliff Moss, committee chairman on section rating; H. E. Miller, chairman of national membership; and F. J. Mooney, assistant secretary in charge of membership activities.

5. Membership would consist of the membership groups A, B, C and D as of the end of the quarterly report at the end of February.

6. Percentages will be figured by dividing the total attendance, including guests, officers, members, etc., by the total membership groups, A, B, C and D.

Group A — Sustaining members
Group B — Members
Group C — Associate Members
Group D — Student Members

7. Figures for attendance shall be taken from the year end report submitted to the national office. The attendance figures should include attendance only at monthly meetings—not social functions.

* * * *

Every part of the country has some particular form of food for which they are well known. One of the things the Saginaw Valley is famous for is beans. For our part of the wager we put on the block a 25-lb bag of beans and recipes for the famous Michigan Bean Soup.

Your part of the wager will, of course, be anything that is edible, along with the recipes for cooking it.

We hope you will accept our challenge and we hope further, that you will contact other sections as we have contacted you and set up contests between you and them. You might win enough food for a free meal for the whole section.

Floyd J. Zdrojkowski
Chairman
"Bean Challenge Contest"
Saginaw Valley Section, AWS
2717 Bradford Dr.
Saginaw, Mich.

SAGINAW FLINGS DOWN GAUNTLET

C. Molenaar (left), Saginaw Valley Section Chairman, accepts giant bag of Michigan beans from T. Kennedy (center), of Michigan Bean Co. as its opening "ante" in membership attendance contest challenge to all other AWS sections. F. Zdrojkowski, bean-challenge contest chairman, helps hold bag

Missouri

QUALITY CONTROL

Kansas City—The *Kansas City* Section opened the 1961 year with a meeting held at the Wishbone Restaurant on January 12th. A dinner and a technical meeting had one of the largest turn-outs experienced in the Section.

The speaker was Harry W. Rogers, general manager of the H. R. Inspection Service of Shawnee, Kan. His subject was "Quality Control in Welding by the Use of Nondestructive Test Methods." Mr. Rogers was formerly manager of Quality Control at the Fluor, Paola, installation and later held the same position with the Taylor Forge & Pipe Works.

The talk consisted of a down-to-earth welding man's explanation of the nondestructive testing methods. Live demonstrations of gamma-ray and X-ray, penetrant and ultrasonic tests were given. He also discussed magnetic particle methods and various tests which he had performed on the Atlas missile vessels in the last few years. He then carefully explained the far-reaching economics obtained with close cooperation between quality control and the welding department in end-product quality. This was brought out to assure the welding divisions that quality control is a helpmate and not a club over their heads. Mr. Rogers also gave some thorough demonstrations after the meeting as a precise part of this discussion.

The attendance, the speaker's talk, and demonstrations were commended.

New Mexico

HARD-SURFACING ALLOYS

Albuquerque — On Thursday, January 12th, a demonstration meeting of the *Albuquerque* Section was held at the Childers Machine and Welding Co. The subject was "Proper Selection of Hard-surfacing Alloys," and the speaker was Albert Zvanut, sales metallurgist for the Stoody Co., Whittier, Calif.

With the aid of slides Mr. Zvanut explained the manufacture of the electrodes, their high yield strength, machinability and extreme toughness. Subcommittee No. 7, of which he is a member, is now working with the consumers in the selection of the electrodes.

The talk was reportedly well received and a lengthy question-and-answer period followed. This was deemed a very successful meeting.

New York

GAS SHIELDED-ARC PROCESSES

Bellmore — The regular monthly dinner meeting of the *Long Island* Section was held on January 12th at Sunrise Village in Bellmore, L. I. Featured speaker at the technical meeting was Kenneth E. Richter of the Linde Co. Development Laboratory in Newark, N. J. The title of his talk was "Gas-shielded Arc-welding Developments."

Mr. Richter's talk was divided into two sections, one on new developments in nonconsumable electrode welding and the other describing new developments in the gas-shielded consumable-wire process.

The development of the pilot-arc starting principle for tungsten-arc welding, which provides reliable arc-starting for spot and continuous applications, was described. A 10-min sound movie was shown describing a tungsten-arc spot-welding machine using four torches on a fully-automated, tape-controlled machine with three axes of motion plus part rotation about a horizontal axis.

Short-arc welding was described as a combination of power supply, feed rate and shielding media; applications such as sheet metal parts, pipe welding and poor fit-up assemblies were described and illustrated by slides. A 4-min high-speed motion picture of short-arc welding was also shown.

WELD FAILURE

New York—An excellent turnout of members and guests was reported to greet Dr. Warren Savage at the January dinner meeting and technical session of the *New York* Section. This meeting was held jointly with the American Society for Metals on January 9th at the Brass Rail on Fifth Ave.

"Why Weld Metals Fail" was the subject chosen by the speaker who is a well-known member of the teaching staff at Rensselaer Polytechnic Institute. Augmenting his oral presentation with excellent slides, Dr. Savage began by differentiating between cracking and microfissuring in both the weld metal and heat-affected zone.

EVENING IN LONG ISLAND

Pleasantries during introduction of guest speaker K. E. Richter (left) by R. Galagarin at Long Island Section meeting on January 12th

NEW YORK MEETS WITH ASM

National Secretary F. L. Plummer, Section Chairman Dan Bellware, and guest speaker Dr. Warren Savage (center) with ASM officers at New York Section meeting on January 9th

Graphs depicting thermal cycles during welding were shown as well as the specialized apparatus designed to measure them. Relationships between ductility during cooling and weldability were given for various types of austenitic stainless steels. Of particular importance were the effects of elements such as columbium and tantalum.

When all variables are accounted for, certain theories can be profferred to explain weld metal failure. On this point, a highly competitive spirit was generated during the question-and-answer period following the lecture. This, and a fine dinner made what was called an extremely enjoyable evening.

AUTOMATIC WELDING

Albany—The development and use of high-speed automatic welding equipment in the automatic, aircraft, missile and nuclear industries was discussed by Dave Kelker, Special Products Department, Air Reduction Sales Co., at the January 5th meeting of the *Northern New York* Section held at the Hot Shoppe, Inc., Albany.

One of a new series of Airco movies, "Automation in Welding" describing the "packaged" welding equipment available for precision welding and illustrating its use was shown following the discussion.

Ohio

LIGHT GAGE WELDING

Cleveland—The *Cleveland* Section staged a panel discussion on "Modern Techniques for Light Gage Metal Welding" at their Dec. 14, 1960, meeting. The discussion followed a dinner-business meeting at the Cleveland Engineering and Scientific Center.

During the business meeting, various committee reports outlined the Spring functions and indicated that there are many activities being planned to expand the use of in the area through welding education. Two functions, a five-meeting educational course on "Cost Reduction in Welded Fabrication" and the 22nd Annual Symposium reviewing "Semiautomatic Welding Processes and Techniques," highlight the coming events.

Aspects of light gage welding were covered during the technical session. Panel members—Anthony S. Graskey of Angle Products Co., John M. Kemp of Barth Corp., Bruce M. MacPherson of Brush Beryllium Co. and Gordon G. Richards of Midland-Ross Corp., analyzed production problems with respect to material handling and fixturing, pointing out advantages of various welding processes on different applications. After a short formal presentation by each panel member, the meeting was opened for an informal question-and-answer session.

EXECUTIVE NIGHT

Cleveland—Over 200 members and their executive guests attended the annual Executive Night Dinner Meeting of the *Cleveland* Section held on January 11th at the Hotel Manger.

Featured speaker of the evening was James J. Nance, president of Central National Bank of Cleveland and past president of Hotpoint and the Studebaker Packard Corp. Mr. Nance's wealth of experience in the field of management made him well qualified to speak on the subject, "Managing Men in the new Economy." The talk pointed up the revolutionary change taking place in the American working force. Reviewing today's business situation which finds more men gainfully employed in service industries than in basic manufactur-

PANELISTS AND NEW OFFICER FOR CLEVELAND

Technical Chairman E. B. Pederson reviews plans at December 14th meeting with panelists. Left to right are: E. B Pederson, A. S. Graskey, B. M. MacPherson, J. M. Kemp and G. G. Richards

Miss Jenine "Darby" Darbyshire is welcomed on December 14th as Cleveland Section secretary-treasurer. Left to right are: C. Berka, C. G. Herbruck, W. Romance, R. Pagenkopf, Miss Darbyshire, T. L. Dempsey, L. Miller and G. Carver

BANK PRESIDENT SPEAKS

Guest speaker at Cleveland Section January 11th meeting: J. J. Nance, president of Central National Bank in Cleveland and former president of Studebaker-Packard Corp. and Hotpoint, Inc.

ing, he analyzed the effect this situation has on management's approach to handling personnel.

Curtis Lee Smith, president of the Cleveland Chamber of Commerce, acted as the meeting toastmaster and briefly reviewed Cleveland's "Erieview" residential and commercial development program.

WELDING OF ALUMINUM

Columbus—The Ohio State University student members hosted guests and members of the *Columbus* Section on Friday, January 13th, at the Ohio Union. Howard Adkins, welding specialist, Kaiser Aluminum and Chemical Sales, Inc., was the technical speaker for the evening. His talk covered the welding of aluminum.

Mr. Adkins introduced his talk by covering the different aluminum alloys and how alloy selections are made. He said improvements in welding of aluminum have widened its use. It was stated that the 5000 series alloys are the easiest alloys to weld and the 2000 series are the hardest alloys to weld. In the past, the nonheat-treatable alloys of aluminum were welded extensively. Now, the stronger alloys are welded too.

After comparing aluminum welding with steel welding, he reviewed the equipment required for tungsten-arc and gas-shielded metal-arc welding of aluminum. The importance of cleaning aluminum prior to welding was stressed. Any by-product of combustion formed by foreign matter in the arc will be a potential contaminant of the weld. Argon and/or helium are employed as shielding gases. Porosity in aluminum welds is controlled by excluding hydrogen from the arc. He recommended filler wire 4043 for welding 3003 base metal, 5556 filler wire to join 5456 base metal, and 5356 filler wire to join 6961 base metal.

In addition to the comprehensive and well-presented talk, a short color film was shown. The film showed how aluminum is used in industry, and slow-motion pictures indicated how aluminum is transferred across the arc during metal-arc welding.

WELDING EDUCATION

Bucyrus—One of the best programs of the *North Central Ohio* Section took place on January 5th at the American Legion in Bucyrus. This was the annual educational meeting of the Section. Attending, in addition to society members, were sixty high school seniors of the surrounding areas, who indicated interest in the engineering field. These young men were accompanied by 15 career guidance counselors from the same high schools.

Prof. Roy B. McCauley, chairman of the Department of Welding Engineering of Ohio State University, spoke on "National Needs in Welding Education." Prof. McCauley is a dynamic speaker. Because of his own enthusiasm for the subject of welding education, it was evident that this enthusiasm permeated through the entire audience.

Prof. McCauley explained how the engineering field "tied things together" as compared to studying a straight science such as physical chemistry. He stated that the United States has only one accredited school offering a welding engineering degree while Russia has many. He explained the three basic areas: weldor—the craft; technician—one or two years post high school training in welding; welding engineering. He stressed how, in welding engineering, the different engineering courses were tied together with specific welding engineering courses to complete the welding engineering field.

Judging from the many individuals gathered around Prof. McCauley after the meeting was adjourned, it was evident that he had started many people thinking seriously about welding education.

The monthly publication by the Educational Committee and Technical Representative was passed out to the group. This month's subject was "Understanding the Fillet Weld."

FLAME CUTTING

Toledo—Forty-six members and guests of the *Toledo* Section met on November 16th at the Toledo Yacht Club to hear a very informative discussion on "Flame Cutting" as given by George R. Spies, Jr., who is presently employed in the Development and Equipment Engineering Dept. of Air Reduction Sales Co., Union, N. J..

His talk, which was accompanied by slides, covered a comparison of the fuel gases, natural gas, propane and acetylene. He pointed out that in beveling operations the economics of fuel costs are considerably different from those of perpendicular cutting. Here acetylene is most efficient, followed by propane and natural gas.

Oklahoma

FLUX-CORED WELDING

Oklahoma City — The *Oklahoma City* Section met on January 10th for dinner and meeting at the Cattlemans Cafe.

J. A. Howery of the National Cylinder Gas Co. Research Laboratories, Chicago, Ill., presented a complete and up-to-date description of the flux-cored CO_2 welding process. A movie describing the process was accompanied by slides showing actual "on the job" applications at various plants around the country to supplement the talk. The general presentation was well prepared and well received by an audience of 40 welding personnel.

ELECTROSLAG WELDING

Portland — The *Portland* Section was honored to have Mrs. R. D. Thomas, Jr., as well as Mr. Thomas for dinner on January 10th prior to the monthly meeting held at the Henery Theiles Restaurant.

After an excellent dinner Mr. Thomas gave the members a rundown on the new United Engineering Center in New York. Also some of the future expectations of the SOCIETY were discussed. After a short break Mr. Thomas gave an excellent talk on Electroslag Welding, showing slides on the subject along with a description of the process.

Pennsylvania

CRYOGENICS

Allentown—The *Lehigh Valley* Section held a joint meeting with the ASM on January 6th in the Jade Room of the Hotel Traylor

in Allentown.

Following dinner, Mel Long of Air Products, Inc., of Allentown, gave a demonstration of the cooling effects of liquid oxygen and nitrogen on various materials.

Henry Mason, also of Air Products, Inc., was the technical session speaker. His subject was on "Materials and Fabrication for Cryogenics." He explained how liquid oxygen and nitrogen is generated from air and the selection and fabrication of materials for equipment to generate, store and use these low-temperature bodies. Slides were used to illustrate the flow processes to generate and liquefy oxygen and nitrogen.

ELECTROSLAG WELDING

Philadelphia—R. D. Thomas, Jr., president of Arcos Corp. and of the SOCIETY, spoke to a group of approximately 80 people at the *Philadelphia* Section's technical meeting held on Monday Nov. 21, 1960. Mr. Thomas has presented many papers before this section.

His subject on this occasion was "Electroslag Welding." As in the past, Mr. Thomas left little, if any, doubt in the minds of his audience just what this process is and what can be accomplished with it.

A point well taken was the fact that electroslag welding is not used in the United States as extensively as in European countries and that —if we as a nation expect to enjoy the world leadership in welding as we have in the past—we must, wherever economics justify them, make use of new techniques.

National Secretary Fred Plummer preceded Mr. Thomas with a brief account of SOCIETY activities.

PHILADELPHIA MEETINGS

Panel members at December 2nd meeting chat with W. Scattergood of Philadelphia Section. Left to right are: L. N. Schupp, W. Scattergood, E. Goehringer and W. Brooks

Commander George F. Moran, U. S. N., discusses Polaris missile at December 19th meeting

PROCEDURE QUALIFICATION

Philadelphia—"Procedure Qualification" as a subject aroused quite a bit of interest at the Philadelphia Section's Dec. 2, 1960, meeting held at the Engineers Club. Panelists were: L. N. Shupp, welding engineer for Graver Tank & Mfg. Co., Field Erection Division; E. E. Goehringer, district manager, The Lincoln Electric Co., and Robert Lewis, welding foreman, Fabrication Division, Bethlehem Steel Co., Pottstown.

The panel covered the why and how of procedure qualification and engaged in a brief discussion on the economic dangers of superfluous procedures.

MISSILES

Philadelphia — Commander George F. Moran, U. S. N., Special Projects Division, Navy Department, furnished the *Philadelphia* Section a rare opportunity for an intimate glimpse into the planning, production and operational problems of the Polaris missile and the missile firing submarines, on Monday, Dec. 19, 1960. The dinner meeting held at the Engineers Club was a joint affair with the Society of Naval Architects and Marine Engineers.

Commander Moran described the physical limits of the Polaris missile, what it means population-wise and geographically, and the many problems particularly relative to submarine use.

Following this most fascinating discussion Ralph Bradway, welding superintendent of the New York Shipbuilding Corp., elaborated on atomic submarine construction and some of the many radical problems involved in the weldments.

PIPE WELDING

Philadelphia—"Pipe Welding" as the subject created considerable discussion at the January 6th panel meeting of the *Philadelphia* Section.

Frank Wenke, superintendent of the Streets Div., Philadelphia Gas Works, was on hand to answer inquiries on welding of the miles of pipe used for gas transmission.

James McLaughlin, piping superintendent, Bechtel Corp., New Castle, Del., explained the methods, procedures, etc., being currently introduced in power piping.

H. A. Sosnin, piping consultant, covered the history of piping, the importance of piping to today's standard of living and just about anything else pertaining to piping anyone can imagine. "Butch" Sosnin came forth with one of his usual, informative, intelligent, forthright, earthy revelations totaly lacking any resemblance of boredom and touched with a splash of humor. The pro's and con's of downhill welding on fixed pipe provoked quite a bit of discussion.

GAS-SHIELDED ARC PROCESSES

Pittsburgh—Sixty-six members and guests of the *Pittsburgh* Section were present at dinner in the Hunt Room of the Webster Hall Hotel on January 18th. Later at the Mellon Institute Auditorium, 129 members and guests attended a meeting to hear Robert T. Telford of the Linde Co., Newark, N. J., give a talk on "Gas-shielded Arc-welding Processes."

The talk was divided into two sections, one on new developments in tungsten-arc welding, particularly the use of pilot arc, and the second on gas-shielded metal-arc welding. The talk was illustrated with color

SPEAKER FOR PITTSBURGH

Gas-shielded arc-welding processes was topic of talk by R. T. Telford at Pittsburgh Section January 18th meeting. Left to right are: H. Cable, R. T. Telford, C. Lytton, H. Child and R. Nourie

"DEEP IN THE HEART OF TEXAS" . . .

Some of the 124 members and guests who attended Houston Section January 18th meeting to hear guest speaker, R. A. Wilson of the Lincoln Electric Co.

Guest speaker, R. A. Wilson, with Houston Section members on January 18th. Left to right are: D. L. Shall, D. J. Middlehurst, R. A. Wilson and L. L. Manchester, Jr. (As added note, Mr. Shall was very active in preparation of Houston Section education program given last year at Rice Institute and to be repeated in 1961)

slides and two color movies. One film showed completely automated tape control machine applying tungsten-arc spot welds to missile components.

HIGH-STRENGTH STEELS

Shickshinny—Dr. Robert D. Stout, Dean of the Graduate School, Lehigh University, was the speaker at the January 4th meeting of the *Susquehanna Valley* Section. The dinner meeting was held at the Foothills Manor in Shickshinny. The topic of Dr. Stout's talk was "Higher-strength Steels for Welded Structures."

Dr. Stout expertly covered a survey of the "accelerated cooling —that is, spray quenching and stress relieving—of several carbon steels and five or six higher strength low-alloy steels such as HY-65, HY-80 and A-302. He emphasized the fact that the low-alloy steels gain in yield strength, ultimate tensile strength, notch ductility and fatigue resistance with correspondingly faster quenches and subsequent stress relief. The results of his studies are confined to laboratory tests primarily performed on base metal and are not based on specific weld configurations. There is a tremendous amount of work still to be done which has been limited by a scarcity of funds available for this type of research.

Tennessee

ALUMINUM WELDING

Johnson City — The *Holston Valley* Section held its regular monthly meeting on Dec. 20, 1960, at the John Sevier Hotel in Johnson City.

The speaker of the evening was Paul B. Dickerson, chief of the welding group at the Process Development Laboratories, Aluminum Co. of America.

Mr. Dickerson's informative talk on "Welding of Aluminum" was supplemented by slides. His talk included such important points as welding of aluminum by the inert-gas processes and the properties of inert-gas welds; it covered present accomplishments as well as projected future trends.

The excellent presentation held the interest of many and resulted in several questions on the process.

LOW-HYDROGEN ELECTRODES

Nashville—An illustrated lecture on "Late Developments of Low-hydrogen Electrodes" was presented by D. C. Helton, research and development engineer for the Harnischfeger Corp., Milwaukee, Wis., at the January 12th meeting of the *Nashville* Section.

The meeting held at the Biltmore Restaurant was preceded by a dinner and social hour.

Texas

MECHANIZATION IN WELDING

Houston—On Jan. 18, 1961, the *Houston* Section met for a dinner meeting at the Houston Scientific and Engineering Society. The guest speaker was Robert A. Wilson, a vice president of The Lincoln Electric Co., Cleveland, Ohio, who directs the company's Application Engineering Dept. Mr. Wilson has pioneered the application of arc welding in all phases of manufacturing including tanks, pipe lines, industrial piping, railroad cards, automobiles, ships and machinery of all types. Mr. Wilson presented an excellent talk accompanied by slide-projected photographs on the topic of "The Rapidly Increasing Trend to Mechanization in Welding."

A very interesting film entitled "Reaching for the Stars"was shown before the dinner.

ELECTRON BEAM WELDING

Ft. Worth—On Wednesday, January 11th, the *North Texas* Section met at Howard Johnson's Turnpike Restaurant for their regular monthly meeting.

The featured speaker for the evening was W. J. Farrell, vice president and chief application engineer for Sciaky Bros., Inc., Chicago. Using slides and a blackboard, Mr. Farrell presented his subject, "Electron Beam Welding," in a most interesting manner. In addition to outlining its principles of operation, Mr. Farrell illustrated a number of practical applications for the process.

The 36 members and guests who ventured forth in unusually inclem-

TOKEN OF APPRECIATION

Guest speaker, W. J. Farrell, is given token of appreciation by E. Mai at North Texas Section meeting on January 11th

ent weather thoroughly enjoyed the meeting.

Washington

STAINLESS STEEL

Seattle—Highlights of the *Puget Sound* Section meeting held at the Engineers Club on Thursday evening, January 12th, were talks by National President R. D. Thomas, Jr. His first talk covered the activities of SOCIETY headquarters. He also presented Prof. Gilbert L. Schaller with the Adams memorial membership award for work in education of welding at the University of Washington.

As his technical presentation, Mr. Thomas discussed an Atomic Energy Commission supported study of the welding of columbium-stabilized 18–8 stainless steel. He briefly discussed one aspect of this ten-year research program in the development of new alloys for the prevention of fissures when welding 347 stainless steel, and he supplemented his talk with illustrative slides.

The audience left with a much greater understanding of the problems involved in stainless steel welding and good background information on how to overcome stainless welding problems.

FLAME FLUXING

San Antonio — The January meeting of the *San Antonio* Section was held at Captain Jim's on the 9th with 45 members and guests present.

Speaker for the evening was Charles Burggraf of All-State Welding Alloys Co., Inc., Arlington, Tex., who selected as his topic of discussion "Application of Flame Fluxing with Acetylene, City Gas, and Propane." To highlight his presentation, Mr. Burggraf had available a series of slides on liquid fluxing of bronze, copper and brass using city gas. Some of the advantages of using automatic liquid-gas fluxing are the elimination of the cleaning operation, little or no flux or burn-off residue, and a much cleaner appearance. Fluxing will remove oxide film on carbon steel, thus cutting the cost of preparation. Much information and knowledge was obtained by the group in the question-and-answer period which followed the formal presentation.

Wisconsin

OVERWELDING

Milwaukee — The *Milwaukee* Section held its regular monthly meeting on Dec. 16, 1960, at the Ambassador Hotel with an attendance of 88 members and guests.

Robert Allen, assistant public relations director for the Milwaukee Braves, was the coffee speaker. Mr. Allen joined the Braves in 1953, one year before graduating from Marquette University. His long service with the Braves enabled him to give some personal stories about the players. He also mentioned new players they have acquired for the next season, and he feels they are putting together a winning team for 1961.

Olgert Riteris, industrial engineer of Bucyrus-Erie Co., was the technical speaker. He discussed the methods for determining expected amount of overwelding. He covered the conditions that cause overwelding and the additional cost which cannot be added to the selling price of the product. He pointed out how overwelding could be measured both in labor and material cost when it does occur.

CINCINNATI SECTION ANNOUNCES WELDING METALLURGY LECTURES

BY DRS. NIPPES AND SAVAGE
OF RENSSELAER POLYTECHNIC INSTITUTE

March 15 — Basic Welding Metallurgy
22 — Practical Welding Metallurgy
29 — Nonferrous Welding Metallurgy
April 5 — Ferrous Welding Metallurgy

7:00–10:00 P.M.
Auditorium, General Electric Co.
Cincinnati, Ohio

$5.00 Students
$7.50 AWS members
$10.00 AWS nonmembers

New Members

EFFECTIVE JANUARY 1, 1961

MEMBERSHIP CLASSIFICATION

A—Sustaining Member
B—Member
C—Associate Member
D—Student Member
E—Honorary Member
F—Life Member

TOTAL NATIONAL MEMBERSHIP

Sustaining Members	200
Members	6,472
Associate Members	5,776
Students	335
Honorary Members	10
Life Members	31
Total	12,824

ANTHONY WAYNE

Hall, O. W. (C)

BIRMINGHAM

Maxson, Floyd (B)
McCampbell, W. M. (B)

BOSTON

Gillis, Harold S., Jr. (C)

CAROLINA

Delk, David H., Jr. (C)
Rhodes, William D., Jr. (B)

CHICAGO

Barnow, Samuel (B)
Smith, Lowell K. (C)
Swantko, Alexander (B)

CLEVELAND

Bottiggi, David D. (B)
Conway, Joseph P. (C)
Simon, Francis J. (D)
Wagner, John (C)

COLORADO

Hardin, Robert E. (B)
Pelican, Thomas L. (A)
Waugh, John Martin (B)

COLUMBUS

Bastian, John C. (B)
Gunther, John Philip (B)

DETROIT

Anderson, Richard W. (B)
Carichner, Harry P. (C)
DeOrnellas, Howard L. (B)
Fagge, Gerald L. (C)
Geiger, Arthur R. (C)
Hamman, Robert M. (C)
Iwaniec, Leonard (C)
Marion, Richard V. (B)
McFaul, John R. (B)
Metz, George P. (B)
Pavel, Louis C. (C)
Powell, Scott W. (B)
Overton, C. N. (B)
Stouffer, Maxwell (B)
Thaxton, Herbert F. (B)
Turner, Harry E. (C)

EASTERN ILLINOIS

Anderson, Verlin B., Jr. (C)
Hazel, John R. (C)
Leichner, H. J. (B)
Nygren, Walfred (C)

HARTFORD

Wilson, Gordon M. (B)

HOLSTON VALLEY

Ager, Ellis Coyne (C)
Gross, Frank L. (C)

HOUSTON

Massey, Richard T. (C)
Williams, Joe R. (C)

INDIANA

Anderson, John E. (C)

IOWA

Millhollin, George R., Jr. (C)

IOWA-ILLINOIS

Bartel, Richard W. (C)
Lanford, Don B. (C)
Smithers, John A. (B)

KANSAS CITY

Mitchell, Lloyd K. (B)

LEHIGH VALLEY

Interrante, Charles G. (D)

LONG ISLAND

Schwenk, Walter (C)
Sullivan, Michael J. (C)

LOS ANGELES

Kushmak, Daniel D. (B)
Altseuller, Samuel Martin (B)
Bolin, Raymond (D)
Hanson, O. J. (C)
Holland, James Monroe (D)
Moody, Olsen C. (D)
Smith, Donald W. (D)
Tilton, Julian (C)

MADISON-BELOIT

Block, Raymond E. (C)
Sparr, S. N. (C)

MAHONING VALLEY

Derrow, Roy, G. (C)

MILWAUKEE

Bangs, Edmud R. (B)
Bretschneider, Edwin (B)

MOBILE

Bonifay, W. R. (B)

NEBRASKA

Marinkovich, Andrew (C)
Morris, Robert A. (C)

NEW HAMPSHIRE

Bodge, Frederick G. (C)

NEW JERSEY

Kramer, Louis W. (B)
Lamb, William J., Jr. (C)
Reid, William R. (C)

NEW YORK

Abbott, Frederick E. (C)
Balestrino, Pier Luigi (C)
Heim, Arthur I. (B)
Rzant, Adolph William (C)

NIAGARA FRONTIER

Ffield, Paul E. (B)

NORTH TEXAS

Taylor, Donnie Joe (C)
Webb, Melvin H. (B)

OKLAHOMA CITY

Dahl, Kenneth O. (C)

OLEAN-BRADFORD

Barnes, Lewis G. (B)
Emery, George F. (B)

ORANGE COUNTY

Crow, Ed. (B)
DeFir, R. C. (B)
McBride, Larry W. (D)

PEORIA

McCollum, Claude L. (B)
Wagner, G. B. (B)

PHILADELPHIA

Linowski, Benjamin J. (D)
Murphy, Joseph J. (B)
Pushkar, John J. (C)
Snyder, Richard H. (C)

PITTSBURGH

Babcock, James N., Jr. (B)
Dombrowski, Henry J. (C)

PORTLAND

Frodl, Ralph F. (B)
Wayne, Paul (D)

PROVIDENCE

Barter, Richard (B)
McKaig, Donald R. (C)
Pierson, Thomas J., Jr. (C)
Silva, Richard E. (B)
Speed, Sidney E. (C)

PUGET SOUND

Burr, Fred L. (C)

RICHMOND

DeeEllen, William (B)
Gerloff, J. G. (C)

SAGINAW VALLEY

Adams, Winston S. (D)
McGowan, Donald E. (D)

ST. LOUIS

White, Thomas T. (C)

SAN ANTONIO

Brooks, Dennis C. (D)
Doan, P. C. (C)
Kincheloe, A. L. (B)
Logan, Charles E. (B)
Shadrock, Frank, Jr. (B)

SAN FRANCISCO

Riggs, Lloyd A. (B)
Smith, Harold C. (C)

SHREVEPORT

Hyde, Robert L., Jr. (B)
Sermons, James L. (B)

SOUTH FLORIDA

Crain, Robert L. (B)

STARK-CENTRAL

Aberegg, Richard E. (B)
Becker, Paul H. (C)
Brother Eugene, F. S. C. (B)

SYRACUSE

Mullett, Samuel A. (C)
Smith, David W. (B)

TULSA

Crabb, Jim G. (C)
Lingle, David L. (C)
Mickelson, J. T. (B)

WICHITA

Boisvert, Robert A. (C)

WORCHESTER

DeBellis, Pasquale A. (B)

YORK-CENTRAL PA.

George, Harry D. (C)

MEMBERS NOT IN SECTIONS

Ellis, George C. (B)
Koike, Masao (C)
Muller, Werner (B)

Members Reclassified During January 1961

PEORIA

Hawes, David H. (C to B)

PHILADELPHIA

Orysh, Milton S. (C to B)

SYRACUSE

Schaefer, Myron J. (C to A)

NEWS of the industry

NEMA Officers

A. D. R. Fraser, Rome, N. Y., president of Rome Cable Div., Aluminum Company of America, was recently elected president of National Electrical Manufacturers Assn., at its 34th annual meeting. Mr. Fraser had been treasurer of NEMA for the past year. He succeeds N. J. MacDonald, Elizabeth, N. J., president of Thomas & Betts Co., Inc. NEMA is the nation's largest trade organization for manufacturers of electrical equipment.

W. R. Persons, St. Louis, Mo., president of the Emerson Electric Manufacturing Co., was elected vice president of the association, and A. E. Pringle II, Philadelphia, Pa., president of the Pringle Electrical Manufacturing Co., was elected treasurer.

British Research Appointments

E. H. S. van Someren recently joined the British Welding Research Assn., as a Principal Scientific Officer and is to work on fundamental studies on the physics of the welding arc by optical observations. He will be joining a team of mathematicians and metallurgists. Since graduating from London University with a special degree in Chemistry, Mr. van Someren has worked in the artificial silk industry; with nonferrous metals in Birmingham, Copenhagen and Odda; and in the photographic industry in London. Since 1958 he has been in the Research Department of Murex Welding Processes Ltd. Mr. van Someren is a Member of the Institute of Metals, and of the Institute of Welding; a Fellow of the Institute of Physics and Physical Society; and an associate of the Royal Photographic Society.

In another move, E. V. Beatson of Joseph Lucas Ltd. was appointed by the Council of the British Welding Research Assn., to serve on the Association's Research Board. His principal fields of interest are resistance welding and brazing, his work on the latter being particularly well known through the book, *Industrial Brazing*, of which he was one of the joint authors.

Toys for Tots

Santa acquired a small army of new helpers in 1960 as Eutectic Welding Alloys Corp., Flushing, N. Y., joined the U. S. Marine Corps annual "Toys for Tots" program. Eutectic provided supplies, personnel and facilities through its nationwide network of service and training centers for the

repair of broken metal toys among those collected for distribution by the Marines to underprivileged children. Above, Rene D. Wasserman, president of Eutectic, welded the first such toy of the campaign in the Eutectic laboratory in Flushing assisted by Sgt. Jack Childs, USMC.

Amperex Appoints Distributor

The Amperex Electronic Corp., of Hicksville, L. I., N. Y., recently announced the appointment of the R. W. Farris Co., Inc., as a distributor sales representative to serve: Kansas, Missouri, Iowa, Nebraska (west of, but excluding the counties of Scotts Bluff, Sheridan, Garden and Deuel), and Illinois (south of, and including the counties of Adams, Pike, Scott, Macoupin, Montgomery, Christina, Shelby, Cumberland and Clark).

The R. W. Farris Co., Inc., will operate from its main office at 406 W. 34th St., Kansas City, Mo., and from a branch at 7811 Carondelet, St. Louis 5, Mo.

Electrical Manufacturers Receive Awards

Three electrical manufacturers were honored at the 34th annual meeting of the National Electrical Manufacturers Assn. through presentation of awards "in recognition of their outstanding personal contributions to the progress of the electrical industry."

Those cited are N. J. MacDonald, Elizabeth, N. J., president of Thomas & Betts Co.; James Finney Lincoln AWS, Cleveland, Ohio, chairman of the board of The Lincoln Electric Co., and Everett Morse, Cambridge, Mass., president of Simplex Wire and Cable Co. Each was presented with McGraw Awards—medals and purses established 35 years ago in a continuing program by the late James H. McGraw, former president of the McGraw-Hill Publishing Co., to encourage constructive thinking and action for the advancement of the electrical industry.

Price Reduction

Air Reduction Sales Co., 150 E. 42nd St., New York 17, N. Y., recently announced a price reduction of more than 20% on their Easyarc line of metal powder stainless steel electrodes. The price reduction is said to permit substantial savings in material costs for many applications such as underlays, overlays and welding of dissimilar metals.

COMING EVENTS

A Calendar of Welding Activity

ASM

Mar. 20–24. 12th Western Metal Congress and Exposition. Pan-Pacific Auditorium, Los Angeles.

SNT

Mar. 20-24. 1961 Western States Regional Convention. Ambassador Hotel, Los Angles.

AWS

Mar. 24–25. Mid-Western Welding Show. Kansas National Guard Armory, Wichita.

Apr. 17–21, 42nd Annual Meeting, Hotel Commodore, New York, N. Y.

Apr. 18–20. Welding Show, New York Coliseum.

IIW

Apr. 11–19. Annual Assembly. Sheraton-Atlantic Hotel, New York, N.Y.

ISA

Mar. 27–31. 4th Symposium on Temperature. Veteran's Memorial Hall and Deshler-Hilton Hotel, Columbus, Ohio.

NAAMM

Apr. 9–15. 23rd Annual Convention. Plaza Hotel, New York City.

AIME

Apr. 12–14. First International Symposium on Agglomeration. Sheraton Hotel, Philadelphia.

SESA

Apr. 17–21. Lecture course on Strain Gage Techniques. Granada Hotel, San Antonio.

WRC

Apr. 19. Annual University Research Conference, Hotel Commodore, New York, N. Y.

IAA

Apr. 24–25. Convention. Boston, Mass.

New NCG Plants on Stream

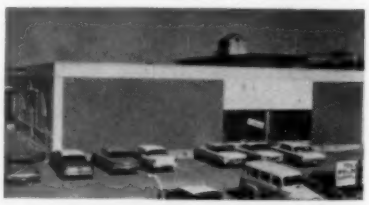
National Cylinder Gas Div., Chemetron Corp., has placed on stream a new acetylene-producing plant and two new transfilling stations to serve the Denver and New Orleans areas.

The acetylene plant, which has a capacity of 1.5 million cu ft a month, and a transfilling station for oxygen, nitrogen and argon have been opened at 1450 5th St., Denver, and will serve customers in Southern Colorado. Plant superintendent is Arthur Greiner.

A new transfilling station at 529 Felicity St., New Orleans, will serve the southern Louisiana area with oxygen. Plant superintendent is Jesse Wolfe.

A. O. Smith Appoints Distributor

The H. R. Toll Co., Minneapolis, Minn., was recently appointed distributor by the A. O. Smith Corp. Welding Products Div. The new welding distributor, according to



Division General Sales Manager R. W. Raney, will strengthen the firm's customer service in the Minneapolis area.

The Minneapolis distributor recently completed work on a new plant and warehouse. The expansion will enable H. R. Toll to better service customer arc welding needs.

Acquires Metal Control Laboratories

Magnaflux Corp. recently announced the acquisition of Metal Control Laboratories, Los Angeles, Calif. This was said to be a major step forward in the company's plan to render a still wider range of materials and development and evaluation services to its customers.

R. A. Wilson, Magnaflux president and vice-president of General Mills, said in making the announcement that Metal Control Laboratories will be operated as a part of the Materials Testing Laboratories Div. of Magnaflux, working particularly closely with the present Magnaflux Laboratories at Los Angeles and Van Nuys, Calif. Jonmore Dickason, who has served as vice president of MCL will continue in the management of the firm's business activities.

INCO High Temperature Engineering Section

A new technical service which will deal with nickel alloys at elevated temperatures was recently established in the Development and Research Division of the International Nickel Co., Inc., New York, N. Y. This section will serve industry on all problems arising in the use of materials in environments at elevated temperatures.

The new section will develop and disseminate technical information in the field of high temperatures, and will also be prepared to give advice on the selection of appropriate materials for high temperature applications.

New Ampco Licensee

The St. Paul Brass Foundry Co., 954 W. Minnehaha, St. Paul, Minn., has signed a licensee agreement with Ampco Metal, Inc., Milwaukee, Wis. As an Ampco Licensee, the 62-year-old Minnesota firm will provide the Twin City area with custom castings of special Ampco copper-base alloys.

Ampco alloys are primarily designed to resist severe metal-to-metal wear, abrasion and corrosion. Ampco castings and products are used extensively in the earthmoving, machine tool, metalworking, food, automotive, chemical and chemical processing, and petroleum industries.

Airco Moves Portland Office

The Air Reduction Pacific Co's Portland, Ore., office has moved its sales, service and warehouse facilities into larger modern quarters at 1325 N. W. Kearney St. in Portland, it was recently announced. For the past 15 years, the Portland office has been at 430 N. W. 10th St.

From the new location, Air Reduction will supply oxygen, nitrogen, argon, helium and hydrogen to its customers as well as a complete line of gas welding and cutting equipment, supplies and accessories; electric arc welding machines; electrodes; and gas-shielded metal-arc and tungsten-inert-gas welding equipment, supplies and accessories. A large area of the new facility has been set aside for the Engineering Service Department where the company will work with its customers on special welding and cutting problems.

The Ohio Chemical Pacific Co., supplier of therapy oxygen, medical gases, anesthesia and other hospital

equipment will also have quarters in this new location. Both Air Reduction Pacific Co. and the Ohio Chemical Pacific Co. are divisions of Air Reduction Co., Inc., New York, N. Y.

SESA Receives NSF Grant

A grant of $45,000 to extend over a three-year period has been awarded by the National Science Foundation to the Society for Experimental Stress Analysis. The purpose is to aid in establishing the new monthly publication, *Experimental Mechanics*, which will become the official journal of the Society.

SESA is an internationally recognized organization devoted to the scientific investigation of static and dynamic effects on materials, the elements of engineering structures and related subjects.

Previously, publications of the Society have been limited to two a year in the field of experimental stress analysis. With the publication of a monthly journal covering the broader field of experimental mechanics, it is expected that a new impetus will be given to many important research problems now awaiting solution.

The first issue of *Experimental Mechanics* made its appearance on Jan. 1, 1961. Headquarters of the Society are located at 21 Bridge Square, Westport, Conn.

Metal & Thermit Plans New Canadian Facility

Plans to construct Canada's first detinning plant at Hamilton, Ontario, were recently announced by H. E. Martin, president, Metal & Thermit Corp., New York, N. Y.

The new facility, to be located on a 7½ acre site, will cost about $1 million, and will be built and operated by the company's Canadian subsidiary, Metal & Thermit Products of Canada Ltd. Ground breaking was scheduled for February 15th. The plant will be completed before the end of the year.

The detinning plant will use the modern alkaline process to remove tin from high-quality tin plate scrap produced in can-making operations. Tin chemicals obtained from the detinning operation will make Metal & Thermit Products the first Canadian source of supply for sodium and potassium stannate, used for plating with tin and for immersion coating of aluminum pistons for internal combustion engines.

Another product of the detinning operation, heavy melting steel scrap, will provide Canadian steelmakers with their first domestic source of premium grade open hearth charging scrap for production of high-quality steels.

Distributor Appointed

Schill Steel Co., Houston, Tex., has been appointed a distributor of the full line of Olin Aluminum mill products, it was announced by the Metals Div., Olin Mathieson Chemical Corp., New York, N. Y. These products include aluminum sheet, plate, coil, rod, bar, extrusions, pipe and tubing.

In addition to its main warehouse in Houston, Schill Steel Co. has division warehouses in Dallas and Odessa, Tex., and Tulsa, Okla. Its Houston building, at 3001 W. Eleventh St., has 175,000 sq. ft. of floor space and functions as a metals service center with modern cranes, saws, shears, flame cutting equipment and other facilities.

Distributor Installs Liquid Oxygen Station

Announcement has been made by Max Clark, president of Jackson Welding Supply Co., Inc., Jackson, Mich., of the opening of a new liquid oxygen storage and conversion station. Jackson Welding Supply Co., an authorized distributor of Air Reduction Sales Co., has been doing business in the Jackson area for over a quarter of a century.

The new station with a liquid capacity of 2700 gal will enable the company to provide oxygen in liquid form to high volume users. Its tank is filled with low temperature liquefied gas supplied via a bulk liquid transport trailer from Airco's liquid air separation plant at Chicago, Ill.

The new station will also permit a more efficient distribution of oxygen in both gaseous and liquid form to the hospitals, metal fabricators and other industries located in southeastern Michigan.

Liquid oxygen cylinders can be filled directly from the tank. Gas cylinders can be filled only after the liquid oxygen has been pumped to a vaporizer that converts the liquid to a gas.

A. O. Smith Concentrates on Houston

"Time on target," artillery jargon for the coordinated massing of firepower on a precise target, was given new meaning in the metal working industry recently when the A. O. Smith Corp. massed its corporate salespower on the welding market in Houston, Tex. The result of the Houston "TOT" was a 3-day welding exhibition attended by about 300 of the area's leading industrialists, farmers, fabricators and contractors.

Teaming up in the saturation sales effort were the Welding Products Div., manufacturer of the welding machines and electrodes on display; the A. O. Smith Corp. of Texas, a subsidiary which manufactures line pipe for the oil and gas industry; and numerous Houston-based sales representatives of the other operating divisions in the diversified firm.

The show featured working demonstrations of the latest techniques and equipment for a full range of welding applications—from utility farm welding to CO_2 production welding. A huge "big top" circus tent on the A. O. Smith Corp. of Texas pipe mill grounds housed the activities.

Names Distributor

Ace Welding & Safety Supply, Inc., 4325 S. Howell Ave., Milwaukee 7, Wis., has been appointed a distributor of Ampco weldrod products by Ampco Metal, Inc., Milwaukee, Wis.

Effective immediately, the new distributor will supply Milwaukee and southeastern Wisconsin with bronze electrodes, bare filler rods and wire in spooled and coiled forms.

Dorsey Gage Expands

The Dorsey Gage Co., Hyde Park, N. Y., manufacturers of precision gages, measuring instruments and related products, have just completed an addition that will double its facilities and manufacturing space. The company has also obtained Allen Linderholm, who has approximately 20 years' experience in gage engineering design and production background; he will be in complete charge of engineering and research, as well as the development of new products.

RWMA Presentation

At their November meeting in Detroit, members of the Resistance Welder Manufacturers' Assn. heard an excellent presentation on the Management of New Products made by S. M. Humphrey and J. W. Bannon of Booz, Allen & Hamilton, Management Consultants.

National Electric Welding Machines Co., Bay City, sponsored

the special program and arrangements were made by Si Fisher, President of National and Vice President of RWMA.

Square D Acquires North Carolina Plant

The Square D Co. recently purchased from Gorham Manufacturing Co. a 98,000 sq ft plant located on 35 acres on the outskirts of Asheville, N. C., according to Lawrence G. Maechtlen, Square D president. The purchase price was not disclosed.

The plant is expected to employ 200 to 300 workers and will serve as headquarters for Square D's Commercial Control Division. "We consider this a most productive addition to Square D's present plant facilities, now totaling more than $2^1/_4$ million sq ft of space for the manufacture of electrical distribution and control equipment," Mr. Maechtlen said. "It is a modern, well-designed structure virtually custom-built for the efficient manufacture of certain of our product lines."

NEMA Reports 1960 Peak

Electrical manufacturing industry factory shipments for 1960 reached a new all-time high of $22,622,300,000—an increase of 5% over the 1959 mark of $21,522,900,000, according to Joseph F. Miller, managing director of the National Electrical Manufacturers Association. The previous peak was $21,900,000,000 reached in 1956.

The above totals include all electrical products, whether or not they are within the Association's scope, and cover shipments by nonmembers, as well as members.

The Association views 1961 with considerable caution, however, and predicts that business, in general, could rise slightly to $22,795,500,000, remain at 1960 levels or drift downward by as much as 5%. Much depends on an anticipated gain in the economy during the latter half of 1961, since it was reported that most electrical manufacturers forecast a slow first half.

Air Products Establishes New District

The opening of a new industrial and medical gas district to supply the Minneapolis-St. Paul area with oxygen, nitrogen, argon, acetylene, hydrogen, helium, medical gases, and a complete line of K-G welding and cutting equipment was recently announced by Air Products, Inc., Allentown, Pa. The company is building a large manufacturing and distribution facility at the Valley Industrial Park, located just south of Minneapolis.

A. V. Brenner has been appointed district manager in charge of the new operation. He has over 20 years' experience in the manufacture, distribution, marketing and application of industrial and medical gases.

D. E. Cummings, general manager of the Industrial & Medical Gas Div., said that the new district is an important link in Air Products' continuing expansion in the industrial and medical gas field. The company now has 13 districts in the eastern and midwestern portions of the United States; Mr. Cummings said that the high level of industry in the area, combined with effective programs for attracting new industry, decided Air Products on its move.

A. O. Smith Farm Welding School

A 30-session farm welding clinic, designed by the A. O. Smith Corp., Milwaukee, Wis., to bring farmers up to date in the theory and practice of welding farm machinery, is currently underway in five Midwestern states. School instructor is John Rehm AWS., sales engineer for the firm's Welding Products Div.

Sponsored by the Farmers Union Central Exchange at sites throughout Montana, the Dakotas, Minnesota and Wisconsin, the A. O. Smith classes stress the fundamentals of welding and practical use of equipment. Various techniques are demonstrated, then performed by the students.

The school has been operated for the last three years. As many as 75 farmers have attended each session, coming as far as 100 miles to the Farmers Union school site.

Farmers Union welding machines and electrodes are supplied by A. O. Smith.

RECIPIENT OF FIRST NCG WELDING GRANT

Welding problem is discussed by James W. Bradley (right), a welding engineering student at Ohio State University, and Prof. Roy B. McCauley, chairman of the university's department of welding engineering. Bradley is first recipient of the National Cylinder Gas Scholarship in Welding Engineering. Married to an Ohio State senior studying business education, Bradley is studying for a bachelor of welding engineering degree and plans a career in welding technology. He is originally from Marysville, Ohio, where his father, William Bradley, owns a welding fabrication shop

NGC welding machine is inspected by City Councilmen Paul Schweitzer (left) and Linwood F. Perkins (right)

Sign Keeps Cleveland Aware of Welding

Recently the Burdett Oxygen Co. placed a new 40 x 90 ft sign in operation on Cleveland's recently improved east shore way. The animated electrically powered unit is located atop one of Burdett's plants and shines toward the throughway along the lake in six brilliant colors and can be seen as far out as a mile on Lake Erie.

A survey revealed that 80,000 cars travel that part of the shore way each day, indicating the value of the location.

About 1800 ft of neon tubing and 45 incandescent lamps animate the figure of a workman cutting steel in a brilliant electric shower of make-believe sparks falling on the Burdett Oxygen name.

In creating the unit, a sign company set up a fabricating shop in its plant to observe a cutter at work and to capture the realism in the sign. An electric eye controls the lighting of the unit.

According to William H. Loveman, president of Burdett, the sign has "already caused so much attention and comment that it has already paid off the investment through its constant advertising of the Burdett name, gases and equipment."

Stocks Safety Tools

Engle's, 46 W. Church St., Orlando, Fla., has been appointed by Ampco Metal, Inc., Milwaukee, Wis., to distribute the firm's line of nonsparking hand tools for use in the presence of inflammable or explosive gases, liquids or powders. The nonsparking characteristic of these copper-base alloy tools eliminates the danger of fires and explosions caused by ordinary "hot" sparks.

NCG Opens Filling Stations

The National Cylinder Gas Div., Chemetron Corp., has placed in operation three transfilling plants to provide local customers with oxygen for medical and industrial purposes.

The plants are at 3091 Market St., San Diego, Calif.; 366 W. 5th St., Salt Lake City, Utah; and 24th and North Santa Fe Sts., Pueblo, Colo. They will receive liquid oxygen from nearby National Cylinder gas production facilities and convert it to gaseous form for delivery to customers.

A. O. Smith Appoints Distributor

Florida Steel Corp., Tampa, Fla., was recently appointed a welding distributor by the A. O. Smith Corp., and will handle the full line of A. O. Smith welding machines and electrodes in the Southeastern United States.

Besides Tampa, Florida Steel has distribution points in Roanoke, Va.; Statesville, N. C.; Atlanta, Ga.; and Jacksonville, Orlando, West Palm Beach, and Miami, Fla. Sales personnel at each of these locations are scheduled for early participation in A. O. Smith's new technical sales training program for distributors. Technical product sessions, designed to enable salesmen to better service their customers' needs, will be held at each location.

Electron Beam Symposium

The Alloyd Electronics Corp will hold its third annual symposium on electron beam technology in Boston on March 23rd and 24th.

The symposium will consist of four sessions. The first two on March 23rd will involve electron beam physics as well as welding and refining. The two sessions on March 24th will include applications of electron beams for advanced techniques such as polymerization and food processing together with present and future applications of electron beams to micro-electronics.

For detailed information, write R. Bakish, Chairman Third Alloyd Symposium, 37 Cambridge Parkway, Cambridge 42, Mass.

Linde Starts Up Oxygen Plant at Great Lakes Steel

Newest addition to the ranks of on-site oxygen plants serving the steel industry is a 500-ton-per-day facility which was placed in operation by the Linde Co., Div. of Union Carbide Corp., New York, N. Y., at Great Lakes Steel Corp. in Ecorse, Mich. Linde President W. B. Nicholson cited the new installation as an excellent example of cooperative planning for the most ecomonical utilization of oxygen in steelmaking.

The Ecorse plant is the third major steel industry installation completed by Linde so far this year. This brings the company's total on-site oxygen capacity for steelmaking to 3623 tons a day. Ten other on-site plants, currently under construction or placed on the planning schedule during 1960, will add another 2605 tons daily by the time the last is placed on-stream in 1962.

New Welding Laboratory

As part of a International Nickel Company's continuing program of expansion and modernization, a new welding laboratory was recently placed in operation at the company's Huntington Alloy Products Div., Huntington, W. Va. Construction of the modern 4000-sq ft facility was completed in December, 1960, and specialized equipment is now being installed.

A major part of the research to be conducted at the new laboratory will be in the nuclear power field for both industry and national defense. Inco has pioneered in the welding of high nickel alloys, cast irons and dissimilar metals.

The new $200,000 laboratory represents a second major expansion of the Huntington Alloy Products Div. laboratory department within the last two years—a $1,500,000 construction and equipment program was completed last spring.

The new welding laboratory reflects an expanded welding research and development program that has three major objectives: research leading to the development of new welding products to meet the stringent requirements of the nuclear age; mill production control to improve the weldability of alloys produced in Huntington; and laboratory aid to help solve customer problems. A team of ten engineers, technicians and laboratory assistants, with specialized training in the welding field, will staff the new laboratory.

Kansas Show Expanded

The Wichita Section of the AMERICAN WELDING SOCIETY has expanded its Welding Show to include exhibitors from areas outside Kansas and has changed the name of the March 24th and 25th event to the Mid-Western Welding Show.

More than 15 of the major manufacturers will exhibit their newest welding products and equipment in the Kansas National Guard Armory in Wichita.

Reports indicate that the hard-working Wichita Section will make the Mid-Western Welding Show an outstanding event of the year.

Foster Wheeler Expands

Construction of a modern, 4400 sq ft office building at the Mountaintop of Foster Wheeler Corp., Mountaintop, Pa., has been completed, according to an announcement by K. L. Walker, works manager. Located near Wilkes-Barre, Pa., the plant was originally built in 1953.

The new addition, a part of long-range expansion plans for the plant, consists of a fully air-conditioned, fully sound-proofed, one-story building attached to the 125,000 sq ft main building. Among its facilities are complete equipment for the reproduction of engineering drawings, both full-sized and on microfilm, and a fireproof storage vault for drawings and microfilm.

Part of the work to be carried out in the new offices will be engineering and drafting details for those products manufactured at Mountaintop.

AIIE Meeting

The Detroit chapter of the American Institute of Industrial Engineers will act as host this year to the Society's 12th Annual National Conference and Convention to be held on May 11, 12, 13, 1961 at the Sheraton-Cadillac Hotel in Detroit, Mich.

The program will include educational conferences, practical work shops and discussions, film sessions, technical papers and industrial exhibits. In addition there will be a one-day symposium for chief industrial engineers. The entire program is designed to provide a variety of modern practical management tools to industry in general.

Information and a brochure may be obtained by writing to James E. McCartney, 12th Annual A.I.I.E. Conference, Room 29, 4181 Oakman Blvd., Detroit 4, Mich.

Solar Aircraft Selects Representatives

Four additional sales firms were recently named as representatives for Solar Aircraft Co. industrial bellows and expansion joints. They are Western Industrial Supply Co., Amarillo, Tex.; Duncan Engineering & Equipment Co., Los Angeles, Calif.; Barnes Engineering Co., Indianapolis, Ind.; and Power & Controls, Inc., Seattle, Wash.

Western Industrial Supply Co., located at 409 Crockett St., Amarillo, will handle the sale of expansion joints and related products in the Texas Panhandle. Duncan Engineering & Equipment Co., 4050 Buckingham Rd., Los Angeles, will cover Southern California, with the exception of San Diego and Imperial Counties; they will also cover Clark County in Nevada. Barnes Engineering Co., Box 55201 Uptown Station, Indianapolis, has been assigned the state of Indiana, while Power & Controls, Inc., located at 5505—17th Ave., N. W., Seattle, will cover the central and western part of Washington.

Vickers Signs Market Agreement

Vickers Inc., Div. of Sperry Rand Corp., Detroit, Mich., has announced the signing of an agreement with the Rosaen Co., Hazel Park, Mich., under which Vickers will market the Rosaen line of Tell-Tale hydraulic filters.

Vickers will sell, stock and service to filters under its own name beginning January 1961. Rosaen will continue to market the units through its own regular distribution channels.

The filters are designed for use on suction, return or pressure lines in hydraulic circuits, and are rated for flows ranging from 2 to 250 gpm. They provide a visual means (mechanical pointer) of indicating when the cartridge should be replaced, and are also available with electrical actuation for remote visual or audible indication by a signal or bell. The electrical signal can also be used to stop the pump automatically.

Western Metal Congress

More than 200 exhibiting firms and 32 important technical sessions will introduce new metalworking ideas and developments March 20–24 at the 12th Western Metal Congress and Exposition in Los Angeles, Calif.

Exhibits will be staged in Pan-Pacific Auditorium and adjacent pavilion. Technical sessions in Ambassador Hotel will be presented by the sponsoring American Society for Metals together with the U. S. Air Force, Aerospace Corp., Metallurgical Society of AIME, American Society for Testing Materials, Society for Nondestructive Testing and Society of Aerospace Materials and Process Engineers.

"Idea Center for Industry West" is the theme of the Congress and Exposition, which are expected to impart many suggestions for betterment of metalworking in the region west of the Rockies.

Norelco Predicts Good Year

Philips Electronic Instruments, Div. of Philips Electronic & Pharmaceutical Industries Corp., 750 S. Fulton Ave., Mount Vernon, N. Y., expects 1961 business to exceed that of 1960 because Norelco instruments are reportedly more widely employed for product control and development than ever before.

"Even though some industries may experience a slower pace during coming months, fortunately we are closely involved with today's trends toward automation, better quality controls and expanded research. Our business level in 1960 improved over 1959 and we expect it to be even better in 1961," according to R. T. Cavanagh, general manager.

During the past year, the Mount Vernon Division has been actively promoting its nuclear instrumentation, tin gages and portable spectrographs in addition to its standard line of products including electron microscopes, X-ray diffraction, spectrographic and industrial radiography equipment. Early in 1961, the first of many Norelco EM-200 electron microscopes will go into service in this country. The company claims this new microscope is the most powerful and versatile instrument of its kind in the world.

The Norelco tin gages were stated to be important in all steel mills in that they serve as a moving X-ray "eye" scans the tin plating on steel sheet as it moves at speeds up to 600 fpm along the production line. The Norelco portable spectrograph was described as a lightweight instrument that can be taken into the field to identify elements and roughly check quantities present in various materials.

Hobart Appoints Distributors

The Hobart Brothers Co., Troy, Ohio, has appointed eight new distributors. General Welding Products, Inc., Louisville 17, Ky.; R & R Welding Supply, Rock Island, Ill.; K & K Welding Supply Co., Williston, N. D.; David F. Edgar, Bagley, Minn.; Southern Welding Supply Co., Spartanburg, S. C.; Coss Welding Supply, Hagerstown, Md.; Welders Sales & Service, Inc., Liberty, Mo.; National Supply & Service Co., Springfield, Mo.

Welding Goggle Distributor

Weber Welding Co., Inc., 5108 Liberty Ave., Pittsburgh, Pa., has been appointed as exclusive distributor in Alleghany County, Pa., by the Glendale Optical Co., Inc., of Valley Stream, N. Y. Complete stocks of welding goggles, safety spectacles, plastic goggles, etc., will be maintained by the Weber organization for prompt supply to retailers, factories, utilities and other users of safety equipment.

New Liquid Hydrogen Plant

Linde Co., Div. of Union Carbide Corp., will build a 26-ton-per-day liquid hydrogen plant at Fontana, Calif., it was announced recently by Morse G. Dial, chairman of Union Carbide. The new plant will supply 21 tons per day of liquid hydrogen to the National Aeronautics and Space Administration under a $31,000,000 contract awarded to Linde by NASA.

The Fontana plant will be the second privately owned and operated plant built by Linde on the West Coast to meet liquid hydrogen requirements for NASA's rocket development programs. Construction of the new Fontana facility is scheduled to begin in mid-1961 for completion by June 1, 1962. The plant will be built on a 30-acre site adjacent to Kaiser Steel's Fontana plant. Source of hydrogen will be coke oven gas.

In addition to meeting NASA's increased demands, the new Fontana plant will also make available bulk and liter quantities of liquid hyrogen to other government agencies and West Coast industries.

Name Change at North American Aviation

North American Aviation, Inc., Los Angeles, Calif., recently changed the name of its Missile division to Space and Information Systems Division. North American President J. L. Atwood said the new name will more accurately reflect the nature of activities to be followed at the Downey, Calif., division.

The Space and Information Systems division will accelerate the development of the GAM-77 Hound Dog air-to-surface missile and more of the corporation's work on manned and unmanned space exploration vehicles, anti-ICBM projects and management of information processing systems will be concentrated there.

Harrison Storms, formerly chief engineer of its Los Angeles division, has been elected a company vice president and now heads the organization at Downey.

Department Name Change

The Allis-Chalmers Manufacturing Co., Milwaukee, Wis., recently announced that the name of Allis-Chalmers pump and compressor department has been changed to the Fluid Dynamics Department. The change in name was made to more properly identify the company's ability to meet today's requirements for supplying fluid systems rather than just products, according to E. F. Greiwe, department manager.

Three Sales Firms Named

Three sales firms were recently named as new representatives for Solar Aircraft Co.'s industrial bellows and expansion joints. They are Tomlinson Steam Specialty Co., Inc., Cleveland, Ohio; DuBois Webb Co., Detroit, Mich.; and Clarence B. Petty & Co., Needham Heights, Mass.

Tomlinson Steam Specialty Co., located at 1599 St. Clair Ave., in Cleveland, will handle the sale of Solar's expansion joints and related products in northern Ohio. DuBois Webb Co. of 19951 James Couzens Highway in Detroit will cover the state of Michigan and part of northwest Ohio. Clarence B. Petty & Co., 50 Kearney Rd. in Needham Heights has been assigned the states of Maine, New Hampshire, Rhode Island and Massachusetts.

Stevens Institute Develops Continuous Metal Process

A new process for the continuous production of commercial sheet metals and alloys was recently announced at Stevens Institute of Technology by the college's Powder Metallurgy Laboratory.

The new process is expected to make possible the production of sheet metals or alloys in a continuous operation, thus saving time, reducing production costs and increasing plant efficiency. In the process metals or alloys in the form of fine powders are suspended in a liquid. The resulting suspension known as a "slip" or "slurry" resembles the pulp suspension used in the manufacture of paper. The "sheets" so produced are continuously passed through controlled atmospheric furnaces where they are brought up to temperatures just below their melting point. Known as "sintering" this heating consolidates the sheets which are then passed through mechanical rolls. A subsequent heating brings the sheets to required density.

The International Silver Co., through its sponsorship of research work at the Powder Metallurgy Laboratory, assisted in the inception of certain phases of the proposed new method.

New Sonobond Demonstration Facilities

R. S. Ames, manager of the Sonobond Corp., subsidiary of Aeroprojects, Inc., recently announced that a new sales-demonstration headquarters has been set up at 202 E. Market, West Chester, Pa. It was stated that increasing sales and customer interest necessitated such facilities where standard ultrasonic metal-joining equipment and techniques could be demonstrated. The facility was established to concentrate in one location, independent of the shops and research laboratories, a selection of standard equipment so that users may be shown the types of equipment available and what can be done with it.

A limited amount of experimentation on customers' problems can be done at the new location according to W. N. Rosenberg, Sonobond director of engineering. However, Aeroprojects will continue to handle all research-oriented problems under the direction of J. Byron Jones, president, in the laboratories at 310 E. Rosedale in West Chester.

Recently an agreement between Aeroprojects and the Aluminum Company of America gave Alcoa-International foreign rights relating to Sonobond ultrasonic metal-joining equipment. Alcoa-International and Sonobond will conduct training institutes for foreign salesmen, sublicensed manufacturers, and customers, probably at the new sales-demonstration headquarters.

PERSONNEL

Alloy Rods Advances Three

M. G. Sedam AWS has been elected president of the Alloy Rods Co. in a realignment of top level administrative posts in which Edward J. Brady AWS, president and founder of the welding electrode manufacturing concern, becomes chairman of the board of directors.

M. G. Sedam, who was formerly executive vice president, will assume his new duties immediately. G. M. Hohmann AWS was elected to fill the executive vice presidency post. He was vice president in charge of production prior to his new appointment.

E. J. Brady as board chairman will continue as chief executive officer.

NEMA Names Welding Section Officers

L. D. T. Berg AWS, manager of the Equipment Marketing Dept., Air Reduction Sales Co., New York, N. Y., was elected chairman of the arc welding section of the National Electrical Manufacturers Association. Mr. Berg succeeds Robert T. Brown AWS, general manager, Welding Products Division, Metal & Thermit Corp.

Marvin G. Sedam, AWS recently elected president of the Alloy Rods Co., York, Pa., succeeded Mr. Berg as vice chairman of the Section.

A graduate of the University of Wisconsin, Mr. Berg joined Airco in 1957. In his present position he directs sales operations for the company's complete line of welding and cutting equipment, supplies and accessories. Before assuming his current duties, Mr. Berg was president of Arcway Equipment Co., a welding equipment and supply distributor. He is an electrical engineer and has had 23 years experience in the welding field.

The Section also elected R. C. Lipps AWS, manager, West-Ing-Arc Dept., Westinghouse Electric Corp., Buffalo, N. Y., as its representative on the Board of Directors of the NEWA Industrial Equipment Division. A. J. Smith AWS, vice president, Electrode Div., The McKay Co., Pittsburgh, Pa., was elected as alternate to Mr. Lipps.

Stone Named Chief Metallurgist

The American Steel Treating Co., Crystal Lake, Ill., recently announced the appointment of Harold C. Stone AWS as chief metallurgist. He will direct all activities of the metallurgical laboratory and will be responsible for all heat-treating specifications and quality control.

Mr. Stone was formerly chief metallurgist for the LeTourneau Westinghouse Co., Peoria, Ill. In addition to AMERICAN WELDING SOCIETY, his affiliations include the Society of Automotive Engineers, American Society for Testing Materials and the American Society for Metals.

M. G. Sedam

H. C. Stone

L. O. Schaefer

L. D. T. Berg

G. M. Hohmann

L. W. Kunkler

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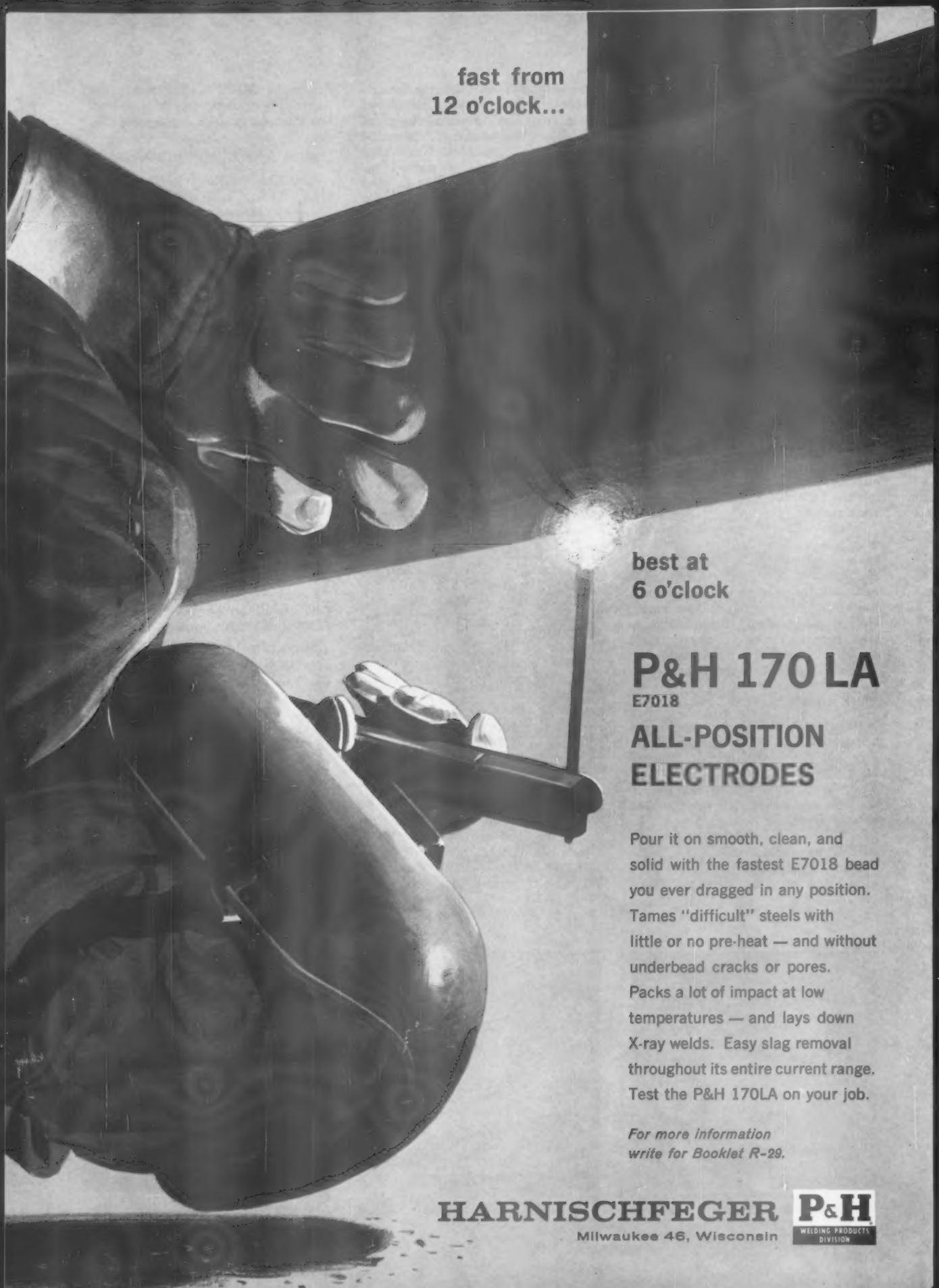

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Oppenheim and Cox Appointed

C. E. Oppenheim AWS has been appointed midwestern regional manager for Alloy Rods Co., York, Pa. E. R. Walsh, III AWS, vice president in charge of sales, in making this announcement states that Oppenheim will headquarter at 445 N. Lake Shore Drive, Chicago, Ill.

Wiley N. Cox AWS has been appointed field representative to serve the Southwestern states area.

Airco Names Mann

H. D. Mann AWS has been appointed assistant manager—engineering services for the Air Reduction Sales Co. district office in Cleveland, Ohio. He succeeds L. W. Kunkler who has been named manager of Airco's district office in Buffalo, N. Y.

In his new capacity, Mr. Mann will be concerned with any customer engineering problems that arise in the district involving Airco's wide range of products.

With Airco since 1946, Mr. Mann was assigned initially to the research laboratories in Jersey City, N. J., as a laboratory technician until his transfer to the equipment marketing department in New York. Before his present assignment he was product sales manager, gas-shielded welding products and processes, in that department.

Shirk Advances

Charles A. Shirk AWS has been appointed manager of the Research Div. of The Austin Co., Cleveland, Ohio. In his new capacity, he will direct and coordinate staff services and operations for the Research Division headed by A. T. Waidelich, vice president for research and engineering.

Mr. Shirk joined the Austin organization 13 years ago as a structural engineer in the company's Chicago District and was placed in charge of the structural design of the 25-million-dollar Automatic Electric Co. plant at Northlake, Ill. In 1957 he was named assistant district engineer in the Chicago District.

A graduate of the University of Nortre Dame, Mr. Shirk holds the degree of bachelor as science in civil engineering. He is a member of the National Society of Professional Engineers and has been certified by the National Bureau of Engineering Registration, with engineering registrations in 18 states.

ASM Elects Scheil

M. A. Scheil was recently elected Secretary for the American Society of Metals and will hold this office through October 1962. He was previously an ASM trustee from 1958 through 1960.

Schaefer Becomes Works Manager

The Austin Co. recently appointed Louis O. Schaefer AWS as works manager of its Steel Fabricating Div., located in Cleveland.

Mr. Schaefer succeeds Loren C. Miller AWS, who has been named assistant manager of the Chicago District of the international engineering and construction firm.

Mr. Schaefer joined the Austin organization in 1955 as a field engineer in the New York District. He later worked as a structural engineer in Roselle, N. J. In 1958 he was assigned to the Steel Fabrication Div.

Mr. Schaefer is a graduate of Drexel Institute of Technology and holds the degree of bachelor of science in civil engineering. He is a member of the American Society of Civil Engineers, the AMERICAN WELDING SOCIETY, the Society of American Military Engineers, the American Society for Metals and the Cleveland Engineering Society.

Lincoln Appoints District Manager

The Lincoln Electric Co., Cleveland, Ohio, has named C. O. Planting, District Manager of their Detroit Sales Territory, to succeed A. F. Boucher who was recently appointed assistant general sales manager.

Planting, who joined Lincoln in 1948 after graduating from Tufts College, Medford Mass., served industry for 12 years in Lincoln's Los Angeles territory, engineering the application of the company's line of arc welding equipment, battery chargers and electric motors.

As Detroit District Manager, Planting will direct the engineering sales activities of Lincoln's sales staff located in Detroit and Bay City.

In addition, Lincoln announces the assignment of George F. Russell AWS to their Canton, Ohio, office and the appointment of Russell Boyles as a field engineer in their Los Angeles territory.

Klumb Appointed Budd District Manager

Eugene F. Klumb was recently appointed district sales manager for the Electronic Controls Section of the Budd Co., Philadelphia, Pa.

Mr. Klumb, who has wide sales and manufacturing experience in the welding industry, will be headquartered in Chicago, Ill. He will assume full sales responsibility to the fabricating and general metalworking industry in the Chicago area.

Prior to joining the company, he held the position of Director of Special Machinery for the Kempsmith Machine Co. His responsibility in-

C. E. Oppenheim

H. D. Mann

C. A. Shirk

cluded all engineering and manufacturing.

Previous to that position, he was a manufacturer's sales representative for the Acro Welding Co.

Kunkler Appointed Manager

L. W. Kunkler AWS was recently appointed district manager of the Air Reduction Sales Co. Buffalo office. As district manager, Mr. Kunkler is responsible for the sale and distribution of all Airco products marketed through the Buffalo facilities located at 1276 Military Rd. Buffalo 17, N. Y. He succeeds R. H. Merriman AWS, who has been transferred to Airco's Philadelphia office.

A graduate of Carnegie Institute of Technology with a B.S. in Electrical Engineering, Mr. Kunkler joined Airco in 1952 as a process representative, eastern region. In 1954, he became district process representative, Pittsburgh district, and in 1956 was made assistant supervisor—technical sales for the same district. Prior to his present appointment, Mr. Kunkler was assistant manager, engineering services for the Cleveland district. His affiliations include the American Society of Metals and the AISI.

Carpenter to Manage Eutectic Center

Richard L. Carpenter has been appointed Manager of the Dallas Service & Training Center of Eutectic Welding Alloys—Southwestern Div., Inc. He was formerly manager of credit and dealer sales for Clearview Corp. in Dallas. He has also been Budget Sales Manager for Seiberling Rubber Co., Garland, Tex., and chief cashier of the City Employees Credit Union, Dallas. Carpenter is an accounting and business administration graduate of Rutherford Metropolitan Business College, Dallas.

From its Service & Training Center in Dallas, Eutectic serves a large area of the Southwest with its more than 200 welding rods, electrodes and chemical aids, and with consulting service on maintenance and repair welding problems. The Center also houses facilities for the Eutectic Welding Institute which offers free training in maintenance and repair welding.

MobilWeld Elects Five

MobilWeld, Inc., Chicago, Ill., has announced the election of Max K. Ruppert as chairman of the board and Earle F. Cox as president. Other officers elected were C. Richard Sherer, vice president; A. J. Frystak, secretary; and R. E. Mitchell, treasurer; the latter two officers also hold executive positions with Poor & Co. Directors are Max K. Ruppert, Earle F. Cox, C. Richard Sherer, Ralph D. Brizzolara and Charles J. Miller.

Mr. Ruppert is president and chief executive officer of Poor & Co., a railroad supplier which owns a majority interest in Mobil-Weld. Mr. Cox is the inventor and developer of a new portable process that officials say will "meet the railroad industry's present unfilled need for welding on location." Industrial companies, are expected to find the portable service particularly useful in overhead installations needing welding on site.

Nottingham Selects Snyder

Appointment of Richard H. Snyder AWS as manager of the Middle Atlantic region has been announced by Walter G. Roe, manager—sales, J. B. Nottingham & Co., Inc., New York, N. Y.

Mr. Snyder will be in charge of sales and service for the company's welding and lighting power and distribution equipment in Southern New Jersey, Eastern Pennsylvania and Maryland, and Delaware. His office is at 724 Abington Ave., Glenside, Pa., a suburb of Philadelphia.

Active in power engineering for more than 30 years, Mr. Snyder was, from 1947 to 1960, general manager of a manufacturers' representative handling electrical equipment. He had previously been active in engineering and executive capacities for electrical manufacturers and an electric utility company. A member of the AIEE, he holds a B.S. in E.E. degree from New York University.

Berryman Made Manager

J. H. Berryman AWS has been appointed manager of the Air Reduction Sales Co. Special Products Dept. in Union, N. J., it was announced by Dr. A. Muller, vice president of the company. In a concurrent move, Robert A. Stone AWS was appointed sales manager of the same department.

As manager of the Special Products Department, which manufactures and sells custom-built welding, cryogenic and gas handling equipment, Mr. Berryman will be responsible for the development of products and processes in these areas from the research stage to the ultimate commercial and industrial

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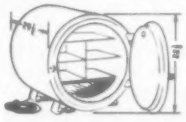

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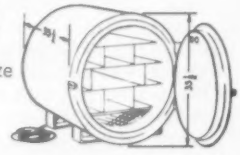

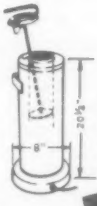

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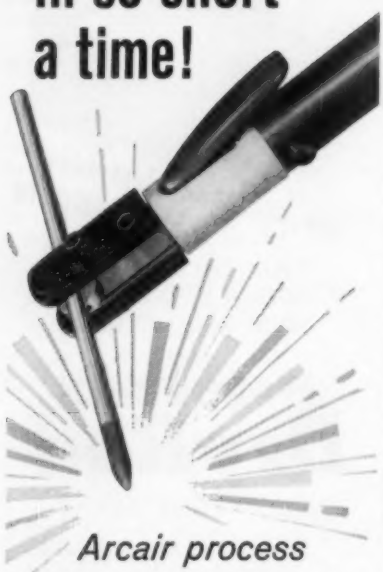

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applications. Mr. Stone will coordinate sales and marketing policies of the department.

A graduate of Johns Hopkins University, Mr. Berryman joined Air Reduction in 1946. Before taking over his present duties he was general sales manager of the Special Products Dept., and prior to this manager of Airco's Machine Welding Dept. Mr. Berryman succeeds C. I. MacGuffie [illegible], who has joined the forward planning group of Air Reduction Co., Inc.

Mr. Stone, attended Temple University in Philadelphia, Pa., and has been with Air Reduction since 1952. Prior to his present appointment he served in the Process Development Section. He has 25 years experience in the welding field and is a member of the AMERICAN WELDING SOCIETY.

Bernard Joins Omark

W. H. "Barney" Bernard has been named assistant chief engineer of the Welding Div. at Omark Industries, manufacturer of construction tools and timber harvesting equipment, John D. Gray, Omark president, announced recently.

In his new job Bernard will be concerned with product development and applications in the stud welding field. He will work out of Omark's Cincinnati office.

Bernard comes to Omark from the Anderson Co., Gary, Ind., where he was sales engineer. Previously, he was chief engineer with Teleflex, Inc., and held various engineering positions with the Dodge Div. of Chrysler Corp.

Lillie Named by General Electric

David W. Lillie has been named manager of the Materials Application and Evaluation Section of the General Electric Research Laboratory, it has been announced by Dr. Walter R. Hibbard, Jr., manager of the Metallurgy and Ceramics Research Dept.

Lillie, born in Brookline, Mass., received his bachelor's degree from Harvard University and later pursued graduate studies at the Stevens Institute of Technology and the Massachusetts Institute of Technology. Before joining the General Electric Research Laboratory in 1954, he was a member of the staff of the Crucible Steel Co. of America, the Massachusetts Institute of Technology, and the U. S. Atomic Energy Commission, where he was chief of the metallurgy branch of the division of research.

Lillie succeeds Dr. James H. Keeler, who has been appointed manager of engineering in the engineering section of the company's Lamp Metals and Components Dept. in Cleveland, Ohio.

Allis-Chalmers Names Two

Appointment of J. S. Quinn as manager of the Omaha district office has been announced by Allis-Chalmers Manufacturing Co. Industries Group. The Omaha district includes eastern, central and part of western Nebraska as well as a part of western Iowa.

Quinn had been manager of heavy industry sales in Allis-Chalmers, St. Louis district and started with the company in 1949. He is a graduate of the Missouri School of Mines.

R. A. Frazee, a representative in the St. Louis district since 1950, succeeds Quinn as manager of heavy industrial sales there. Frazee has been with Allis-Chalmers since 1948 and is a graduate mechanical engineer of the University of Oklahoma.

Van Alsburg Named

J. S. Van Alsburg, formerly of Chicago Bridge & Iron Co.'s Chicago office, has been assigned to the company's International Division sales office in New York, N. Y. Mr. Van Alsburg has been with CB&I since 1955. His experience includes service as an engineer at the Chicago plant and erection district and as assistant to the erection manager in La Salina, Venezuela.

Foote Mineral Names Bliss

The board of directors of Foote Mineral Co. recently announced that it had named L. G. Bliss as board chairman. Mr. Bliss will continue to serve as president and will assume the new responsibilities in addition to his other duties.

The chairmanship has been vacant since the retirement on Nov. 30, 1960, of Gordon H. Chambers.

Bogan Named Manager

The appointment of Robert F. Bogan as manager, industrial marketing for the Pullman-Standard Div. of Pullman, Inc., Chicago, Ill., effective Jan. 1, has been announced by T. P. Gorter, vice president in charge of sales for the company.

As manager, industrial marketing, Bogan will direct a group of Pullman-Standard industrial representatives in working with the railroads

and shippers in determining needs for new and improved railway equipment designs.

In making the announcement, Gorter said that Pullman-Standard is establishing the new department in recognition of the rapidly increasing demands of the transportation industry for special devices to reduce damage and cut costs of materials handling and transportation.

R. T. Huggins Named

R. Troy Huggins has been assigned as an assistant engineer to the materials management department at Allis-Chalmers Norwood (Ohio) Works.

A graduate mechanical engineer of Virginia Polytechnic Institute, Huggins recently completed the Allis-Chalmers training course for graduate engineers.

OBITUARY

E. J. W. Egger

E. J. W. Egger, region engineer for Linde Co., Div. of Union Carbide Corp., died suddenly, Sunday, January 22nd, at his home in Bellevue, Pa. He was 63 years of age.

Mr. Egger was born in Union, N. J., and graduated in 1921 from the Stevens Institute of Technology with a B.S. degree in mechanical engineering. He joined Linde in 1922 as a research engineer in New York City and was transferred to Pittsburgh in 1932. Since that time he has contributed to all the major developments involving oxygen in the steel industry.

Mr. Egger was the past president of the Pittsburgh Chapter of The AMERICAN WELDING SOCIETY and a member of the American Institute of Mining and Metallurgical Engineers. He was also a member of Sigma Nu Fraternity. Mr. Egger is survived by his wife, a son and daughter, and five grandchildren.

William Finneran

William Finneran AWS, Chicago district sales manager of A. O. Smith's Welding Products Div., died recently at his home. A graduate of Brown University, Finneran joined A. O. Smith as a welding salesman in 1951. He was transferred to the Chicago office in 1954, and promoted to district manager shortly thereafter. His former district includes Northern Indiana, Illinois and Eastern Iowa, headquarters at 8312 S. Chicago Ave.

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For copies of articles, write directly to publications in which they appear. A list of addresses is available on request.

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Retort Brazing Turns Out High Strength Honeycombs. *Steel*, vol. 145, no. 25 (Dec. 21, 1959), p. 100.

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Gas-Shielded Welding for Everyday Use, F. Collins. *Welding & Metal Fabrication*, vol. 28, no. 5 (May 1950), pp. 193–197.

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Abstracts of Current PATENTS

prepared by Vern L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington, D. C.

2,936,517—Method and Apparatus for Brazing Fins to Tubes—John W. Brown, Jr., Lakewood, and Arvid C. K. Nihlen, Oberlin, Ohio, assignors to Brown Fintube Co., Elyria, Ohio, a corporation of Ohio.

This new method relates to the making of externally finned tubes. In the method, a retaining member in the form of a continuous member wound into a series of resilient convolutions is diametrically expanded so that the continuous member can be contracted to engage a plurality of longitudinally extended fin members, each having a base portion and a fin portion. The continuous member brings the base portion of the fin members into contact with a tube and retains them in that position so that bonding metal, which is supplied to the contacting surface of the fin members and the tubes, can be fused so as to bond the fin members to the tube. Thereafter the retaining member is expanded and withdrawn.

2,937,083—Hard-surfacing Weld Deposit for Cast Iron—Raymond F. Sherwin, Highland Park, Ill., assignor to The Chicago Hardware Foundry Co., North Chicago, Ill., a corporation of Illinois.

Sherwin's patent covers a weld deposit produced by heating a welding rod having a detailed analysis as specified in the patent. This rod, while heated to a plastic stage is applied to a cast iron surface, the welded area is covered with a heat insulating material, and then the welding area is permitted to cool to final shape.

2,937,262—Method of Attaching Stud to Titanium Bodies—James K. Baxter, Euclid, Ohio, assignor to Thompson Ramo Wooldridge, Inc., a corporation of Ohio.

Baxter has obtained a patent on a method of securing a stud to a titanium body wherein the method comprises heating an area of the body to a molten condition. Then the stud member is pressed into the molten area of the body and permitted to bond to the body by solidification of the molten metal.

2,937,965—Welded Wrought-aluminum Bronze Article and a Method of Heat Treating the Same—John F. Klement, Milwaukee, Wis., assignor to Ampco Metal, Inc., Milwaukee, Wis., a corporation of Wisconsin.

Klement's new article comprises a generally cylindrical rolled shell formed of an alpha phase aluminum bronze alloy containing from 5 to 8% aluminum and having certain specified strength characteristics. An aluminum bronze alloy weld joins the ends of the shell and the weld has substantially all alpha phase metallographic structure. The weld also has a chemical composition and physical properties substantially similar to the metal forming the shell.

2,938,105—Stud-welding Apparatus—Frank K. Kelemen, Haddonfield, Lawrence P. English, Haddon Heights and Oscar H. Darlington, Jr., Pennsauken Township, Camden County, N. J., assignors to KSM Products, Inc., Merchantville, N. J., a corporation of New Jersey.

The novel stud-welding apparatus comprises a welding gun including means for holding a stud, means including a solenoid for moving the stud-holding means in lift direction, and resilient means for moving the stud-holding means in a plunge direction. Other elements are present in the apparatus so that when the stud-holding means disengages from the stud following the welding of a stud to a workpiece, a current flow is interrupted to a relay means which, when de-energized, closes a switch to energize the solenoid and move the stud-holding means in lift direction.

2,938,106—Welding Gun—Lowell H. Hawthorne, Verona, N. Y., assignor to Revere Copper and Brass Inc., Rome, N. Y., a corporation of Maryland.

Hawthorne's new welding gun has an elongate generally cylindrical manual support, a longitudinal carrier element rotatable in the support which has mounted therein an elongate gun barrel comprising a longitudinally spaced rearward head and a forward head. Several tubes are secured to and extend between the rearward head and forward head in such a way that water can be circulated through certain of the tubes extending between the heads to flow through certain of the associated spaces. Other means are present to lead an electrode through the heads to a nozzle carried by the forward head and other means are provided to discharge a shielding gas through the nozzle.

2,938,107—Series Arc-welding Circuit—James K. Pease, Milwaukee, Wis., assignor to A. O. Smith Corp., Milwaukee, Wis., a corporation of New York.

The present patent is on a welding circuit for series arc welding where at least a pair of series arcs are maintained one each between a pair of adjacent consummable electrodes and a workpiece to continuously deposit the electrodes upon the workpiece. A source of current suitable for arc welding is provided and includes a pair of terminals adapted to be connected one each to each electrode and including a third terminal intermediate the pair of terminals and adapted to be connected to the workpiece. A pair of electrode feed means are individually connected one each between the immediately located terminal and the pair of terminals and are responsive to voltage variations between the corresponding electrode and the workpiece to vary the feed of such corresponding electrode.

2,938,108—Arc-welding Electrode—Charles Volff, Sevres, France, and Guy Savard, Vaudreuil, Quebec, Canada; said Guy Savard assignor to l'Air Liquide, Societe Anonyme pour l'Etude et l'Exploitation des Procedes Georges Claude, Paris, France.

This new arc-welding electrode is a continuous stranded electrode for arc welding. It includes a core wire and a wrapping consisting of from one to three helically wound concentric layers of evenly spaced wires. Fluxing material is also present in the intervals of the wires leaving a portion of the outer surface of the wrapping exposed for electrical contact. The patent specifies other details of the wires, and brings out the fact that the volume of the flux material is at least 72% of the volume of the wires.

2,938,993—High-frequency Electrical Welding—Wallace C. Rudd, Larchmont, N. Y., assignor to Magnetic Heating Corp., New Rochelle, N. Y., a corporation of New York.

Rudd's new process relates to welding a longitudinal edge of one metal portion to the longitudinal edge of another metal portion. In the method, said portions are rapidly advanced and brought together for pressure contact at least by the time they reach a predetermined weld point. A final heating zone is maintained along the edges shortly in advance of the weld point by a heating current of a frequency of the order of 100,000 cps or higher. Such edges are preheated in advance of the final heating zone to a temperature lower than welding temperature by producing heating currents therein of a frequency of the order of about 10,000 cycles or less to provide heat sumps along such regions and to check dissipation of heat from the edge surfaces in the final heating zone.

2,938,994—Electric Arc - welding Apparatus—Paul Christiaan van der Willigen, Leon Frits Defize and Jan Anthonie van Bergen, all of Eindhoven, Netherlands, assignors to North American Philips Co., Inc., New York, N.Y., a corporation of Delaware.

This new electric arc-welding apparatus comprises a nozzle forming a chamber for flow of protective gas therethrough and means to supply an electrode to the nozzle at the outlet opening thereof. Other means are present to prevent the formation of welding material deposit upon the surface of the nozzle, which means include a massive body and a driving mechanism to bring the body into impact with the nozzle.

2,938,995 — Adjustable Machine-tool Fixture for Welding Electrodes and the Like—John E. Tracey, Reisterstown, and Elwood L. Wheeler, Owings Mills, Md., assignors to Bendix Aviation Corp., Baltimore, Md., a corporation of Delaware.

This patent covers a specialized machine tool fixture for supporting an electrode in a controllable and resettable manner with relation to a supporting frame means.

2,938,996—Dual-piston Welding Gun—James R. Carswell, Huntington Woods, Mich., assignor to Delta Welder Corp., Detroit, Mich., a corporation of Michigan.

Carswell's construction relates to a hydraulic welding gun wherein a piston and an electrode actuator are provided for supporting the electrode. Resilient means are provided between the piston and electrode actuator so that when the piston has moved to its limit of movement and engages the work, the spring can cause the actuator to move toward the work when the work has become plastic due to heating action thereon.

2,938,997—Welding Device—Arthur W. Anderson, 423 Bedford St., La Habra, Calif.

A specialized welding device is covered by Anderson's patent. This apparatus is designed to deposit weld metal on the circumferential surfaces of an object carried by a rotatable spindle in the apparatus. Other means supply welding flux and a welding rod to the rotating object and other control and positioning means are provided in the apparatus of the invention.

2,941,064—Method of Welding Sheet Steel Members Having Liner Sheets—Ralph H. Gieser, Jr., and John R. Thomson, Park Forest, Ill., assignors to Rheem Manufacturing Co., Richmond, Calif., a corporation of California.

This new method relates to the fabrication of tanks and the like with different sections each having a backing sheet of steel and a separate liner of aluminum on one side thereof. In the method, the sections are placed in engagement with the steel sheets in opposed spaced relation and with the liners interposed between the steel sheets and in contact with each other. The steel sheets are electric resistance seam welded together by exerting pressure against the exposed sides of the sheets sufficient to expel substantially all of the aluminum in the pressure area and to weld the sheets together in such area. The welding current is also passed through adjoining sections adjacent to the steel weld area without the application of the welding pressure but with the current being such that the aluminum liners in such adjacent area will be fused together.

New Literature

Revised AWS Welding Definitions

The AMERICAN WELDING SOCIETY has announced the availability of a new revision of AWS standard welding terms and their definitions. It is the first revision in 12 years and many changes have been incorporated and much new material added. This is considered to be the most important standard published by the SOCIETY and it is a dictionary of welding.

A new Master Chart of Welding Processes has been prepared in conjunction with the AWS definitions. The 39 recognized welding processes are presented in a new layout designed for ready reference. Colors are used for the first time to separate the various welding processes and this provides instant identification. The Master Chart is available in 2 sizes; an $8^1/_2$ x 11 in. size for desk use and a 22 x 28 in. size for wall use.

Copies of the AWS definitions (including desk chart) may be obtained for $2.00 per booklet. Copies of the wall or desk chart may be obtained separately at a list price of $1.50 and $.50 respectively, from the AMERICAN WELDING SOCIETY, Dept. T, 33 W. 39th St., New York 18, N. Y.

AISC Steel Standards

Two new standard steel specifications were recently released by the American Institute of Steel Construction, 101 Park Ave., New York 17, N. Y.

The specification and loading tables for open web steel joists (longspan or L-series) has also been adopted by the Steel Joist Institute and supersede the earlier AISC-SJI jointly-adopted specification which has appeared in the AISC manual of steel construction since 1955. The objective of this new specification is to insure satisfactory finished appearance while keeping construction costs in line.

The specification for architecturally exposed structural steel is a completely new standard.

For your free copy, circle No. 51 on Reader Information Card.

Ultrasonic Testing

Nondestructive Testing Bulletin 00-105 is now available from the Sperry Products Co., Div. of Howe Sound Co., Danbury, Conn. Twelve-pages long, it describes the Sperry line of ultrasonic testing equipment, portable industrial X-ray and Magnetic Particle inspection equipment and supplies.

For your free copy, circle No. 52 on Reader Information Card.

Film on In-plant Motion Pictures

A new informational film, depicting many of the ways motion pictures can serve industry, is now available on loan from Audio-Visual Service, Eastman Kodak Co., Rochester 4, N. Y.

"Movies At Work," a 16-mm color and sound production, illustrates the wide range of in-plant films which can be made at low cost with versatile Kodak 16-mm equipment. The advantages of "do it yourself" productions—to tailor films to meet specific problems—are emphasized.

In its 14 min length, "Movies At Work" demonstrates that the motion picture is a valuable tool in industrial communications, and urges that this tool be given consideration when the next problem in communications arises.

In-plant motion pictures were said to serve many causes. Among those illustrated in the film are safety instruction; time-motion analysis of specific jobs; slow-motion studies of machine operations to pinpoint trouble spots; training of new employees for assembly operations, or of regular employees in a new procedure—with the added advantages of narration by their foreman; supervisory and sales-training films in which "interviews" are staged to allow the subject to see himself as his contacts see him; time-lapse films for traffic studies or to determine the most efficient use of plant space; and filmed reports to supplement standard reports from branch operation managers.

Equipment illustrated in the film includes the Cine-Kodak K-100 Camera and Cine-Kodak K-100 Turret Camera, the Kodak Analyst Movie Projector, and the Kodak Pageant Sound Projector, Magnetic-Optical model.

For details, circle No. 53 on Reader Information Card.

Bronze Die Alloy

Ampco Metal, Inc., 1745 S. 38th St., Milwaukee, Wis., has issued Bulletin G-55 which describes a new hard bronze die alloy for drawing, forming and bending stainless and clean mild steels. The alloy was developed after several years of laboratory wear tests and actual field work.

The alloy—DiBronze—is said to have greater toughness, improved impact resistance and machinability, and greater resistance to wear and abrasion than previous bronze die alloys.

For your free copy, circle No. 54 on Reader Information Card.

Gas-shielded-disk Welding Torches

The availability of Bulletin NH-142 describing the new NCG A-10 automatic torch for MIG and TIG welding and the new AM-7 gun for semiautomatic welding has been announced by the National Cylinder Gas Div., Chemetron Corp., 804 N. Michigan Ave., Chicago 11, Ill.

The gun and torch have interchangeable barrels, and diagrams show how the gun is fitted with an adjustable pistol grip and the torch can be mounted singly or in a standard mount holding two torches for parallel or tandem welding. Features of both units are listed.

For your free copy, circle No. 55 on Reader Information Card.

Metallic Carbide Coatings

Up-to-date physical data and characteristics of flame-plated coatings are covered in a series of bulletins just prepared by Linde Co., Div. of Union Carbide Corp., 270 Park Ave., New York 17, N. Y.

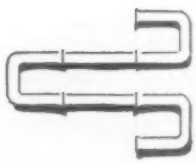
Bulletin F-1246-A lists the compositions and physical constants for the following coatings for metal

GOT A JOINING PROBLEM?

Having trouble with corrosion? Dissimilar or unusual metals? Successive joints on the same work? We'll tackle it . . . at no cost to you.

Tough joining problems gave this company its start. Every time we solved a problem we had a new customer . . . and often a new product to sell! That's how we got into the special alloys business in 1946. That's how we grew.

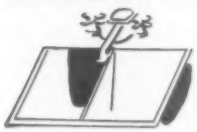
FOR EXAMPLE



Automobile air conditioning units called for a low-cost but highly corrosion resistant heat exchanger with freon-tight seals in aluminum tubing. ALL-STATE developed a cadmium-zinc alloy that was low in cost, resistant to all atmospheric conditions, and leak-proof. Same alloy now used for repair of automobile radiators.

Our 430° non-acid flux was developed for joining stainless with minimum hazard to users. A subsequently discovered application was joining Hydro T-metal without discoloration.

It took months to figure out how to braze the cathode wire to the terminal inside radio vacuum tubes without blackening the inside of the tube. Our silver-copper-indium alloy lowered brazing temperature without increasing vaporization rate, solved the problem.



Stainless steel kitchen sinks became economically feasible only after we helped a manufacturer solve the problem of a perfect color match with a monel gas welding rod.

We still like tough joining problems. That's why we invite you to put your joining problem up to us. We may fail or succeed, but we'll work on it with the best research brains and equipment, and it won't cost you a penny.

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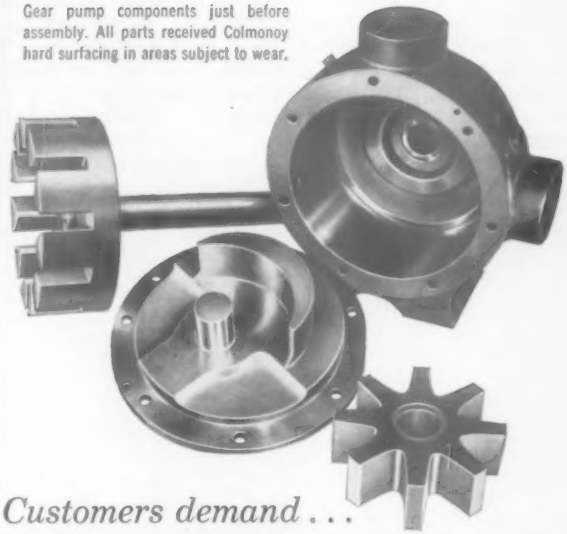
Gear pump components just before assembly. All parts received Colmonoy hard surfacing in areas subject to wear.



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Pump users know Colmonoy lengthens pump life . . . some manufacturers who know they know it now provide Colmonoy protected parts in new pumps.

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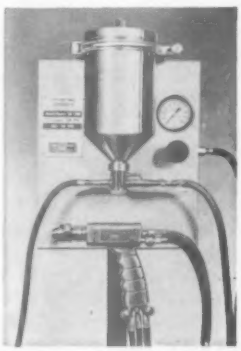

Above: The Colmonoy Sprayweld unit. Left: Colmonoy overlay on pump rotor being finish ground. Below: The Spraywelder Catalog and Colmonoy Manual. Ask for them.

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parts: Coating LW-1, tungsten carbide +6–8% cobalt; Coating LW-IN30, tungsten carbide +13–15% cobalt; Coating LW-lN40, tungsten carbide +15–17% cobalt; Coating LW-5, 25% tungsten carbide +7% nickel + mixed carbides; Coating LC-1A, 85% chromium carbide +15% nickel-chromium; and Coating LA-2, 99% + gamma aluminum oxide.

Bulletins F-9889-B, F-1435 and F-1436, respectively, give a more detailed listing of the physical and chemical properties and applications of the three tungsten carbide-cobalt coatings supplied by the company.

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X-ray for Heaters

A new technical bulletin (Technical Bulletin No. 5), describing the application of X-ray equipment in the inspection of fuel oil heater elements, has been announced by Balteau Electric Corp., 5 New St., Stamford, Conn., manufacturers of industrial X-ray machines.

The two page, illustrated folder was reprinted from the *U. S. Navy Bureau of Ships Journal* and was written by N. G. Wayne and J. F. McKenna, Jr., of the Boston Naval Shipyard. Included are photographs of radiographed elements along with reproductions of exposed X-ray film, graphs, etc.

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Thermit Welding

Basic instructions, covering step by step operations in the repair of broken shafts, rolls, machine frames and other heavy parts by the thermit welding process are given in a 6 page illustrated data sheet now available from Thermex Metallurgical, Inc., Lakehurst, N. J.

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Electro-Magnetic Relays

A new 16-page, 2-color catalog showing the complete P&B line of electro-magnetic relays is now available from Potter & Brumfield Div., American Machine & Foundry Co., Princeton, Ind.

Comprehensive engineering data on 42 different series of relays is included. The various relays are divided into four major groups: telephone type, military, power and general purpose. Most of the information is presented in the form of charts for ready comparison between like kinds of relays.

Mounting data and descriptions of a wide variety of enclosures is given, as well as information on various terminals.

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Rust Prevention

Tested and proved procedures said to prevent and remove rust under almost any conditions are detailed in Service Bulletin No. 16B, recently issued by Oakite Products, Inc., 19 Rector St., New York 6, N. Y.

The bulletin covers such common industrial problems as the safe removal of rust from raw stock by the use of inhibitors or inhibited acid compounds; prevention of hydrogen embrittlement during rust removal by the use of alkaline derusting agents; the simultaneous removal of rust and grease while conditioning surfaces for painting; the prevention of rust between processing operations, and during periods of storage; the washing of parts by machine or tank immersion with simultaneous protection against rust; and antirust conditioning of steel in preparation for painting.

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New NBS Publication

"Screw-thread Standards for Federal Services, 1957, Part III." *National Bureau of Standards Handbook H28* (1957) is available. It amends in part H28 (1944) (and in part its 1950 supplement), issued Oct. 7, 1960.

This volume is the third of a series of three into which the 1957 edition of *NBS Handbook H28* is divided. It covers Acme, Stub Acme and Buttress threads; rolled threads for screw shells of electric lamp holders and unassembled lamp bases; microscope objective and nosepiece threads; surveying instrument mounting threads; ISO metric threads; miscellaneous threads; Class 5 interference-fit threads, trial standard; and wrench openings.

The Handbook represents the work of the Interdepartmental Screw Thread Committee, which is sponsored by the Departments of Defense—Army, Navy, Air Force—and commerce to promote uniformity in screw-thread standards in the Departments concerned.

The Handbook may be ordered from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. 66 pages; 60¢.

Regular Data

A light-pressure industrial regulator with more than 96,000 different industrial applications now possible because additional component stock parts are now interchangeable, according to Modern Engineering Co., 3401-15 Pine Blvd., St. Louis 3, Mo. For regulation of compressed air and all noncorrosive commercial gases; inlet pressures up to 3000 psig and outlet pressures up to 500 psig are permissible. Illustrated literature describes major features designed for superior operation and long service life.

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Hard Surfacing Data

A 4-page, 8½ x 11 illustrated 2-color Engineering Data Sheet (No. 55) entitled "Hard Surfacing Austenitic Manganese Steel with Colmonoy No. 1, Special No. 1 and Colmonoy No. 2" was recently made available by the Wall Colmonoy Corp., 19345 John R St., Detroit 3, Mich.

The data sheet discusses typical uses of manganese steel and the need for hard surfacing. It also includes complete recommendations for application of the three alloys. Illustrations of typical hard surfaced parts for improved wear resistance, accompany the discussions.

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Storage Water Heater Bulletin

Following closely the recent announcement of a major expansion program, Niagara Weldments, Inc., 55 Portage Rd., Niagara Falls, N. Y., has introduced a line of fully standardized Storage Water Heaters under the trade name "NiaWel," described in Bulletin No. 61.

The all-new line includes 55 sizes in both vertical and horizontal models plus a choice of 114 heating elements, all conforming to ASME specifications throughout. Tanks are of welded, flange quality steel construction. Removable, U-tube heating elements are construction of seamless drawn Admiralty or copper tubing.

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You can learn more about Sciaky Electron Beam Welding, fully automatic TIG and MIG Welding with modular or building block concept, and the newest in Bench Welding at the

A.W.S. Welding Show, New York Coliseum April 18, 19, 20, Booth 729

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Dye Penetrants

"A Sneak Preview to Your Free Showing of How to Locate Flaws with Dye Penetrants" is the title of a four-page pamphlet issued by Turco Products, Inc., 24600 S. Main St., Wilmington, Calif.

The folder describes Turco's 23-min, 16-mm sound and color training film on dye penetrant inspection methods. It also contains a number of action photos, clipped from the film. Parts actually inspected during the film include: aircraft wing spars, pressure vessels, small parts, wheels, gears and brake plates.

For your free copy, circle No. 63 on Reader Information Card.

Filters for Electrode Cooling

A study has been issued by the Rosaen Co., 1776 E. Nine Mile Rd., Hazel Park, Mich., to show how a filter made by this company and equipped with limit switch greatly increases life of resistance welder electrodes by shutting off the welder before the filter becomes so clogged that it would allow dirt to enter the narrow water passages of the electrodes.

The study is the result of more than a year's experience in a large automotive plant. It shows that savings effected far outstrip the cost of the filters. Electrodes, ignitron tubes and rectifiers are protected. Downtime for cleaning filters is said to prove much less than when electrodes had to be replaced due to improper cooling. Production is correspondingly greater on a pieces-per-day basis. Imperfect welds reportedly are fewer.

For your free copy, circle No. 64 on Reader Information Card.

Welding Equipment for Thin Metals

A new short-form catalog describing the thin metal welding equipment line is now available from the Vacuum Tube Products Div., Hughes Aircraft Co., 2020 Short St., Oceanside, Calif.

The catalog illustrates nine different power supplies and eight different weld heads and handpieces. The power supplies range from 5 kva half cycle a-c unit through a 500 w-sec stored energy unit. Specifications are shown for all units. They feature an extremely short discharge time, metered controls on the stored energy models and standard production bench sizes for easy installation.

Welding heads and handpieces, designed for a variety of applications ranging from medium duty to extremely fine precision spot welding, are illustrated. All weld heads feature low inertia to allow for quick follow-through on welds. The catalog also describes the company's free weld evaluation service. Weld feasibility studies, first level testing, and metallurgical analysis are part of the services offered to customers.

For your free copy, circle No. 65 on Reader Information Card.

Alkaline Cleaner

A strongly alkaline cleaner designed for "really rugged" cleaning jobs, is described in Service Bulletin No. 17B, recently published by Oakite Products, Inc., 157 Rector St., New York 6, N. Y.

Designed originally to remove such stubborn soils as burned-on oil, heavy grease and dirt from railroad equipment, the cleaner has proved its cleaning power in many other applications. It may be used in the cleaning tank or in steam cleaning operations. It may be used with safety on steel, iron, brass, magnesium and other metals, but is not recommended for aluminum or zinc. Solutions of the compound clean fast, and have long life in the tank. They may be mixed with solvent detergents to remove certain soils, such as asphalt, which resist straight alkaline solutions.

For your free copy, circle No. 66 on Reader Information Card.

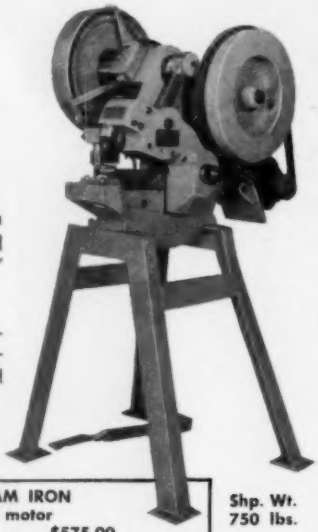
Large and Small Fabricators of steel and ornamental iron swear by it ...

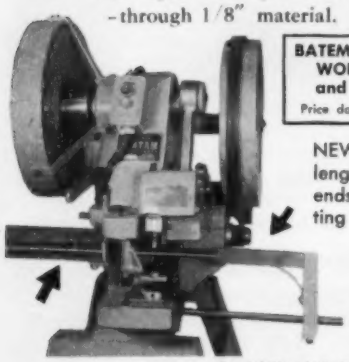
BATEMAN BANTAM IRON WORKER

The Bantam cuts and punches fast and clean . . . no grinding necessary. It's versatile, and saves time and labor! Cuts 2" x 2" x 1/4" angle and 1/4" x 4" flats.

Punches 1/2" hole through 1/4" material. Operates by hand or foot, uses 3/4 hp motor (1750) rpm., powered with flywheel and drive gear.

The Coper will cope 1-1/4" -through 1/8" material.





BATEMAN BANTAM IRON WORKER, with motor and stand $575.00

Price does not include Blades, Punches or dies.

Shp. Wt. 750 lbs.

NEW ACCESSORIES: Gauge for cutting to length, Guide for Flat Bars for cutting on ends, and Angle Iron Trimming Guide, for cutting at a 45 degree. Write for details.

WRITE TODAY for complete information and name of nearest distributor

Bateman Foundry & Machine

MINERAL WELLS, TEXAS

For details, circle No. 17 on Reader Information Card

OF NEW BOOKS

(Book reviews obtained from foreign periodicals by Gerard E. Claussen, contributor of "World-Wide Welding News.")

Researches on Welding Stress and Shrinkage Distortion in Japan. Vol. 4 of 60th Anniversary Series, The Society of Naval Architects of Japan, 185 pp. Tokyo. Price $3.80.

During the past 13 years 113

NO FLEXING... NO BENDING
NO "KINKS" AT ALL in the...

You Convert the TEC Pencil Torch in Seconds Into a Miniature 45° Angle or 90° Angle Torch!

Off-set Nozzle Off-set Chuck
A durable Vycor nozzle, transparent so you SEE WHAT YOU WELD coupled with an easy adjusting "non-slip" chuck.

Just a quick twist of the fingertips and you can TEC weld in practically any area in only 1½ inches of space and also enjoy:

"TIP-OF-THE-TORCH" COOLING SO YOU WELD CONTINUOUSLY AT 300 AMPS!
Continuous coolant water reaching the tip of the torch affords cool, continuous welding at 300 amps.

GUARANTEED GAS AND WATER LEAKPROOF!
One-piece unit torch head without threaded fittings or gaskets to wear or leak eliminates gas and water leakage.

UNPARALLELED MANEUVERABILITY!
Lightest weight, only 3 ounces, fine balance and miniature head mean exceptional handling in only 1½ inches of space.

MAINTENANCE ELIMINATED!
Simplicity of design with no moving parts eliminates replacement parts. Quality workmanship assures years of service.

Still insist you've got a welding problem? If so, consult TEC

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TEC TEC TORCH COMPANY, INC., CARLSTADT, N. J.
MANUFACTURERS OF VISUWELD EQUIPMENT

For details, circle No. 18 on Reader Information Card

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granular tungsten carbide

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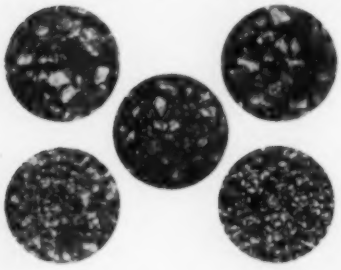

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- For application in the petroleum, agriculture, construction and mining industries whose equipment is subject to extremely rugged, abrasive duty.

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For details, circle No. 19 on Reader Information Card

papers on residual stresses and distortion created by welding have been published in Japan. The book published in English by the Society of Naval Architects of Japan and the Shipbuilders Association of Japan is a compilation of the important results described in the papers. It is not merely a review of literature, but a coherent treatment of the subject by four of Japan's outstanding researchers in this field—Prof. H. Kihara, University of Tokyo; Profs. M. Watanabe and K. Satoh, University of Osaka; and K. Masubuchi, Transportation Technical Research Institute, Tokyo.

The subjects dealt with are:

1. Mechanism of development of welding stresses.
2. The hydrodynamic analogy for analyzing welding stresses in butt welds.
3. Effects of residual stress on brittle fracture and buckling strength.
4. Mathematical theory of shrinkage distortion.
5. Effect of welding procedure and external constraint on distortion.
6. Buckling caused by welding.
7. Stress relief and spot heating to remove distortion.

The book is a good combination of theory and experimental results. It does not cover the effect of welding stresses on weld cracking and fatigue, nor the methods of measuring residual stresses.

—•—

Guide to Design Criteria for Metal Compression Members. Hard Cover, 8½ x 11 in., 99 pp. Column Research Council Engineering Foundation, Ann Arbor, Mich. Price $5.00.

The purpose of this book is not to supplant, but rather to serve as a guide to the improvement of existing design procedure and specifications. The goal is to serve all specifications by offering guidance toward improvement. An effort is made in the Guide to present both refined and simplified procedures which they deem preferable.

A major thesis of this book is the unification of all centrally-loaded column design on the basis of the modified Eulerian (tangent modulus) theory. A very important factor in modifying the strength of columns is the presence or lack of end restraint. This is considered in some detail; it is believed that specs in the United States should give increased attention to this important phase of column design, which is usually considered in European practice.

This is an extensive treatment given to compression-member details with consideration given to the various possible cross sections. The length of a column is a requisite of the structural function but the designer has latitude in the choice of cross section. He should select that cross section providing the largest possible radius of gyration without encroaching on clearance requirements or unduly increasing the cost. A detailed analysis is given of all pertinent cross sections and their use.

Buckling of laterally unsupported columns is also considered and simple formulas are derived for various afflictions. The limitations of these simplified approaches are also discussed.

The last part of the Guide deals with columns that are eccentrically and/or laterally loaded (termed herein the beam/column). Various degrees of complexity in design procedures are discussed. A number of recommended design approaches are given.

The initial edition of the Guide does not cover the subjects of local buckling in plate girder webs, plate girder stiffener design, nor buckling of pony truss chords. Continuing research in these fields has suggested the postponement of this coverage until a later edition.

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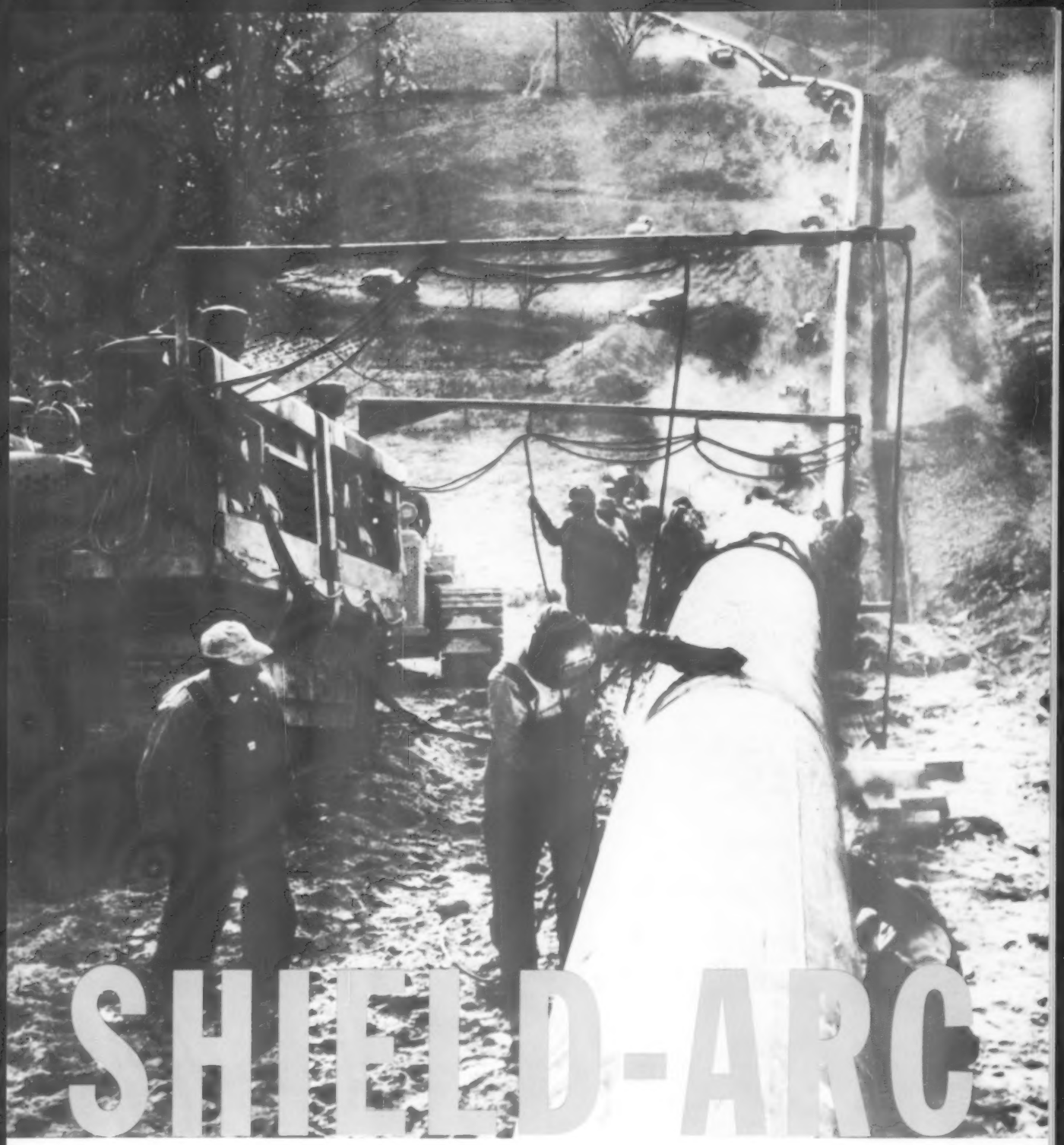
ANNUAL MEETING AND EXPOSITION

APRIL 17–21 IN NEW YORK CITY

For details, circle No. 20 on Reader Information Card →

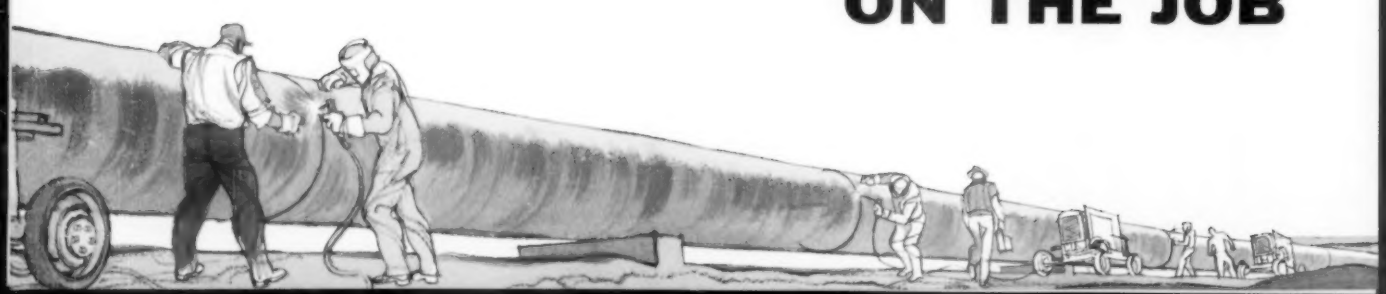


Stretch. Crane your neck. Squint. As far as you can see pipe—you'll see Lincoln Shield-Arc engine welders laying down metal. Why so many Lincolns? Because this contractor—after trying other makes—proved for himself that Shield-Arcs are unquestionably the best for day-in, day-out durability, operator appeal, reliability, low cost. The next few pages show why.

All-welded harbor warehouse in Long Beach, California, made architectural history as one of the largest, open-span buildings ever constructed. Contractor used Lincoln SA-200 welders which operate at low engine speed, require little maintenance, assure utmost reliability. The Lincoln SA-200 is by far the most popular gas engine welder ever built.

Even Louisiana swamps can't bog down these welding workhorses. Right this minute Lincoln machines are at work all over the world in the toughest imaginable field conditions—in jungles, Arctic ice packs, deserts. They're there on pipelines, refinery and building construction jobs because each part, from engine to brush holder to box-section frame, is built to give an extra margin of service, even when going is toughest.

THESE ARE LINCOLN SHIELD-ARCS ON THE JOB



Lincoln Shield-Arcs perform as well high in the Colorado mountains as they do at sea level thanks to the generous surplus power delivered by oversized engines. This reserve power means full generator output, no power drop-off even from older machines which have seen years of service. You get consistently excellent performance, low-cost maintenance, longest life with Lincoln Shield-Arc engine welders.

All construction welding is easy and trouble-free when you use Lincolns. They keep costs down, profits up. Weldors know, like and do their best with Lincoln machines. Dual Continuous Controls let operator select exact machine settings he knows will do the job best—whether flat, vertical or overhead. Idling device and design efficiency keep fuel costs low.

Chicago Bridge & Iron Company operates 685 engine-driven welders . . . 660 of them are Lincolns. Williams Brothers Company has 161 Shield-Arcs . . . all are Lincolns. Bechtel Corporation has 353 machines . . . 351 are Lincolns. And Pittsburgh-Des Moines Steel Co. has 53 at Neville Island . . . all Lincolns. There are many good reasons why these companies and others rely so heavily on Shield-Arcs.

Lincoln has a full line of gas or diesel machines . . . one for any job. Each is powered by a thoroughly proved-in-service Hercules, Continental or General Motors engine that will keep on running long after other equipment has given out. Idling device drops engine speeds to low idle to conserve fuel when not actually welding, automatically picks it up to operating speed when the arc is struck.

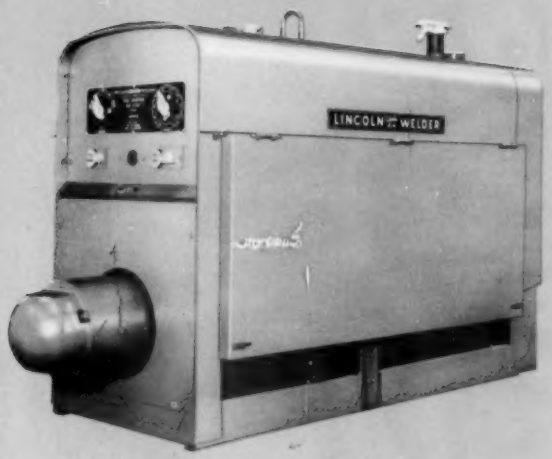
Each is equipped with Dual Continuous Controls which let a weldor select both welding heat and arc characteristics to suit his own technique. Once set, Lincoln Shield-Arcs hold their output indefinitely, won't drop off after extended use. This means better results on such critical work as stringer beads. Rugged, lightweight box-section bases on all Lincoln engine welders can stand the gaff when the going gets roughest.

Why don't you get this kind of rugged dependability and sure-fire welding performance? Put Lincoln Shield-Arc engine-driven welders on your construction jobs. Get all the facts from your local Lincoln Field Engineer . . . a specialist in welding.

LINCOLN WELDERS

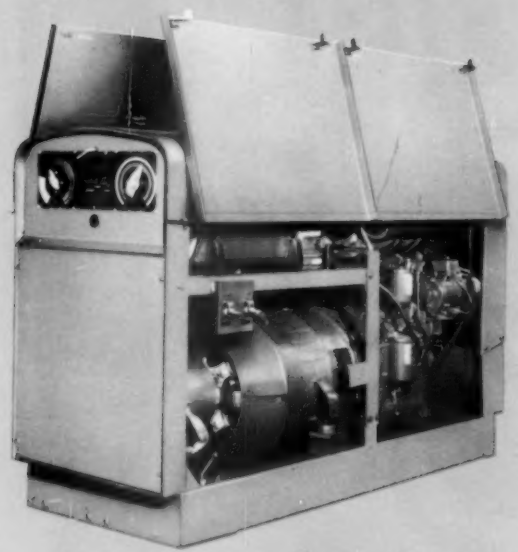
SA-200 Most Popular 200-Ampere Engine Welder Ever Built

MODEL	SA-200
Current Rating (NEMA) at 40 volts	200 amps
Duty Cycle	60%
Current Range	40 to 300
Engine	Continental
Horsepower	36 @ 1450 rpm



SAE 300, 400 and 600 Machines Deliver Full-Range of Welding Currents

MODEL	SAE-300	SAE-400	SAE-600
Current Rating (NEMA) at 40 volts	300 amps	400 amps	600 amps
Duty Cycle	60%	60%	60%
Rated Current Range (amps)	60-450	80-600	120-750
Engine, 6-cylinder	choice: Hercules or Continental	Hercules	Hercules
Horsepower	47 @ 1400 rpm	63 @ 1400 rpm	82 @ 1400 rpm



Need Diesels? Pick from SAE 250, 300 and 400 Diesel Engine Welders

MODEL	SAE-250	SAE-300	SAE-400
Current Rating (NEMA) at 40 volts	250 amps	300 amps	400 amps
Duty Cycle	60%	60%	60%
Rated Current Range (amps)	50-325	60-450	80-600
Engine	Continental	GM	GM
Horsepower	35 @ 1700 rpm	35 @ 1675 rpm	50 @ 1625 rpm

THE LINCOLN ELECTRIC COMPANY
Dept. No. WW-7
Cleveland 17, Ohio

The World's Largest Manufacturer of Arc Welding Equipment and Electrodes

LINCOLN WELDERS

New Products

A-C, D-C Inert-gas Welding Machines

Two all-purpose a-c, d-c, inert-gas-shielded arc welding machines have been announced by Hobart Brothers Co., Troy, Ohio. Model ADI-2641 is rated 200 amp and model ADI-3641 is rated 300 amp. By changing a switch, or by the use of simple plug-in controls and accessories, they can be used for manual, automatic, tungsten inert-gas, inert-gas spot or gas-shielded-arc consumable-electrode welding.

Both models have new broad welding ranges which permit welding with as little as 1 amp of welding current. Model ADI-2641 has a welding range of 1 to 300 amp ac or 1 to 350 amp dc. Model ADI-3641 has a welding range of 1 to 375 amp ac or 1 to 410 amp dc. Both models are equipped with an automatic contactor-opening feature, hand switch for remote control, adjustable post flow timer, automatic high-frequency control, power factor correction and a ballast resistor to stabilize the a-c inert-gas welding current.

No cables to change is a convenient feature of the machines. Welding cables for both tungsten- and metal-arc welding remain permanently connected, as a separate terminal provides for connecting the tungsten-arc torch. The operator merely flips a switch to choose between the two welding methods.

Both machines are designed for operation from single-phase 230/460 a-c power.

For details, circle No. 101 on Reader Information Card.

Explosive Gas Detector

A new instrument for the detection of dangerous or explosive vapor mixtures has been introduced by the Instruments and Systems Section of the Industrial Equipment Div., Engelhard Industries, Inc., 75 Austin St., Newark 2, N. J. Called "the Bilge Bug," the device is primarily intended for use aboard boats but may also be used advantageously in industrial or other locations to detect concentrations of gasoline, natural gas and many other combustible vapors.

Consisting of a control and indicator panel, a sensor unit and a connecting cable assembly, the Bilge Bug is supplied for two operating voltages of 6 and 12 v dc, and draws a current of only 1.2 amp. The sensor unit is installed in any location where combustible mixtures may collect.

In operation, the switch is turned on, and a pilot light indicates proper operation and illuminates the face of the meter. Within seconds, the two platinum wire sensing elements will react to the presence of vapors and indicate the condition on the meter. Following the check, if the reading is "safe," the instrument may be turned off and the engine started.

For details, circle No. 102 on Reader Information Card.

Stored-energy Power Supply

The development of a medium-range electronic welding power supply with a range selector switch for finer control at low settings and an automatic lockout to prevent premature discharging has been announced by the vacuum tube products division of Hughes Aircraft Co., 2020 Short St., Oceanside, Calif.

The new power supply is designated the VTW-32. Its range selector switch allows either a 1 to 25 w-sec or a 10- to 250-w-sec range. The 1- to 25-w-sec range provides an expanded meter scale, and increases the stability of energy stored at low ranges. Switching from one range to the other automatically discharges any stored energy, changes the meter calibration and allows the power supply to charge to the new setting.

For details, circle No. 103 on Reader Information Card.

Gas Cylinder Cart

Smith-Byrd Co., Inc., 1968 Tuxedo Ave. N. E., Atlanta, Ga., has announced an entirely new conception in the safe and convenient transportation of high pressure welding gas cylinders.

The Smith-Byrd cart reportedly is designed for maximum safety to eliminate the hazard of dangerous personal accidents from the dropping of conventional two-wheel carts and to provide maximum safe and easy carrying of gas and cylinders. A fire wall is provided between the oxygen and fuel gas cylinders. The cart is pulled from the front so that objects can be spotted and avoided which might cause accidents. Because of its extremely low center of gravity, it is difficult, if not almost impossible, to tip the cart over, thus reducing the potential hazard of broken valves. The cart provides handy carrying space for an unusually large number of tools for welding rods and provides a wrap-around bracket for hose. In the loading position, the cart is extremely easily loaded and in the carrying position is high enough off the ground to provide generous floor clearance. Other features are zero pressure tires and antifriction bearings.

For details, circle No. 104 on Reader Information Card.

New Line of Inert Arc A-C Welding Units

A new line of M&T Murex inert-arc a-c welding machines has been announced by Metal & Thermit Corp., Rahway, N. J. Three models have NEMA-rated outputs of 200, 300 and 400 amp. The design features a reportedly simplified,

foolproof gas afterflow device which eliminates the need for complicated timers. Also incorporated is a spark gap oscillator, with silencing circuit included, which produces high-frequency pulses for instant starting and arc stabilization.

The transformer uses patented dual-coil construction that delivers balanced wave output for smooth operation, high starting voltage and high power factor. Stepless current control is achieved with a minimum-travel steel core to minimize chatter.

Automatic remote control is provided for high frequency, gas and water by means of a switch which may be attached to the welding torch. Primary power may also be controlled by this switch on certain models. At the end of a weld, gas afterflow continues for a preset period of time and then shuts off automatically.

For details, circle No. 105 on Reader Information Card.

Molybdenum-tungsten Powders

Molybdenum-tungsten alloy powders, newly developed for production of true solid-solution alloy products, have been added to the product line of the Chemical and Metallurgical Div., Sylvania Electric Products, Inc., Towanda, Pa.

Two grade series, MA-28 and MA-39, are being offered. Each grade normally will be supplied in three different percentage compositions, although any desired composition can be produced since molybdenum and tungsten form a continuous series of solid solutions.

The MA-28 grades contain a minimum of 99.8% molybdenum-tungsten alloy with all impurities closely controlled. Reported to be designed primarily for powder-metallurgical processing into rod and wire, they can also be used for pressing and sintering into large ingot forms for forging, rolling and machining.

MA-39 grades contain a minimum of 99.9% molybdenum-tungsten alloy with impurities controlled to minimum levels. These grades are for use where ultrahigh purity, low oxygen content or larger particle size is required.

For details, circle No. 106 on Reader Information Card.

Cobalt Radiography Cameras

A new line of cobalt-60 radiography cameras has been announced by Radionics, Inc., Lafayette & Water Sts., Norristown, Pa.

Model 60 machines have capacities of 1, 5, 10, 30 and 100 curies of

cobalt 60, respectively, with weights ranging from 190 to 1100 lb. They are designed primarily for panoramic and internal radiography, where the machine is used to position the source as required. All of the units may be obtained with provisions for containing and using more than one radioactive source. The operator has a choice between a stronger or a weaker cobalt-60 source, or between a cobalt-60 source and an iridium 192 source.

For details, circle No. 107 on Reader Information Card.

New Process for Welding Mild Steel

Air Reduction Sales Co., 150 E. 42 St., New York, N. Y., has

introduced a new welding process—called Aircomatic CO_2 Sprayarc—for welding of mild steel which combines the use of carbon dioxide and a low-alloy steel welding wire.

The new process employs the economies of CO_2 welding with features of gas-shielded arc welding of steel and requires no special equipment. The process produces a quiet, spatter-free type arc for quality when used with a new, specially treated A602 Aircomatic wire.

Advantages are spatter-free welding, open arc, spray-type transfer, good weld appearance, sound welds, economical deposition rates, continuous wire feed for high work factor and low cost CO_2-shielding gas.

Laboratory data and field trial results indicate that essentially no spatter is produced when proper techniques are used. Sound welds can be made using direct current, straight polarity using CO_2-shielding gas. Conventional Aircomatic equipment can be used.

The process open arc provides ease in welding, with a visible arc length of approximately 1/8 in. About 32 v is recommended for most work. Under some conditions, a self-peeling light film of slag appears in the weld; this is readily removable by dragging a chipping-hammer along the weld, or by simple wire bushing.

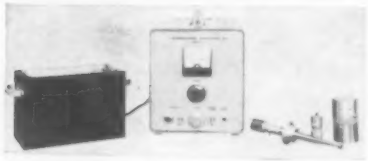
Typical applications for the new process are in tubing, landing mats, die posts, piping, car frames, compressor casings, pressure vessels, farm machinery and machine mountings.

The new Airco A602 type wire can be used for single or multipass mild steel applications with deposition rates varying from 7 to 15 lb/hr depending on size of wire and amperage. All metal tensile tests showed an ultimate tensile strength of 70,000 psi and a yield strength of 60,000 psi. Wire is available in 0.045 and 0.054 in. diameter.

For details circle No. 108 on Reader Information Card.

Flexible Ultrasonic Generator

A compact and highly flexible 100-w ultrasonic generator, suited to a wide variety of ultrasonic applications, is available from International Ultrasonics, Inc., 1697 Elizabeth Ave., Rahway, N. J. The Inson 100 PW generator has connections for any of 10 output impedances, which may be selected from a broad range to match any impedance requirement. Any nominal frequency may be specified from 10 to 100 kc or greater.



The wide range of output values suits the Inson 100 PW to ultrasonic welding, soldering, splicing and sealing of metals and plastics, ultrasonic cleaning, ultrasonic drilling and use with processing cylinders or other specialized transducers. Power output is continuously variable from zero to full power.

Frequency range of the standard unit is 35–45 kc, and impedances are 17.5 to 20,000 ohms. Other frequencies and impedances are available on special order.

For details, circle No. 109 on Reader Information Card.

Welding Ignitrons

Coaxial welding ignitrons, developed by the General Electric Power Tube Dept. Schenectady 5, N. Y., are reportedly expected to lead the way to design of new, more compact welding contactors.

The advantage of the coaxial design is said to be that both anode and cathode terminals are at the top of the tube. This eliminates several inches of cathode terminal which protrude from the bottom of the standard welding control tube. Another space-saving feature of the coaxial terminal is that it eliminates bus bars required by standard ignitrons when used in inverse parallel.

Latest additions to General Electric coaxial ignitron family are the GL-7669 for size B welders and the GL-7671 for size C welders. Both tubes are designed for use in standard 60-cycle welding applications.

In a-c control service, two GL-7669's in inverse parallel control 600 kv-amp at voltages of 250 to 600 v over a frequency range of 25 to 60 cycles. In a-c control service, two GL-7671's in inverse parallel, control 1200 kv-amp at voltages of 250 to 600 over a frequency range of 25 to 60 cycles.

Both new tubes are sealed, stainless-steel-jacketed and water-cooled. The GL-7669 weighs 3.6 lb and the GL-7671 weighs 8 lb.

For details, circle No. 110 on Reader Information Card.

Cutting Machine

The Ty-Sa-Man Machine Co., 1226 White Ave., Knoxville, Tenn., announces the development of a new low-cost, gantry-type, multiple-head flame cutter that handles plate up to 20 ft wide and any length.

The new cutter, which derives its economy from lightweight fabrication as opposed to heavy cast

members, uses the Ty-Sa-Man saw gantry which is a standard production item. It reportedly has an unlimited capacity for squaring large plate sizes, scarfing, beveling and edge preparation to close precision tolerances, and can be converted to a straight-line automatic welding rig.

The gantry unit is recommended for use with two end trimmers which also travel on the rails with the gantry and provide cross-cut trimming by means of a movable blowpipe which travels along the transverse rail on roller bearings.

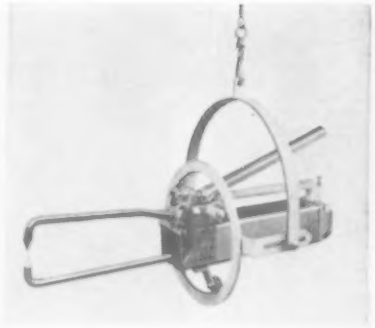
The gantry ripping unit can be fitted with up to eight variable angle blowpipes for production multiple cutting.

Track travel consists of a Thy-Mo-Trol infinitely variable speed drive through a synchronizing cross shaft and a rack and pinion drive to each rail. It is all pushbutton controlled with speed indicator in inches per minute feed and has a 100 fpm rapid traverse rate.

For details, circle No. 111 on Reader Information Card.

Spot Welding Accessory

LMSW-52 spot welding units with a recently introduced "Gyro-Bail" to take the weight off the operator's hands was recently announced by the Miller Electric Mfg. Co., Appleton, Wis.



Functioning equally well from boom and counterweight or spring-loaded cable, the gyro-bail equipped spot welder instantly adjusts itself for any angle of approach and use with minimum effort. Fatigue, errors and accidents are all markedly reduced where the gyro-bail has been tried.

Requests for information may be directed to J. G. Waldron, advertising manager for the Miller Electric Mfg. Co.

For details, circle No. 112 on Reader Information Card.

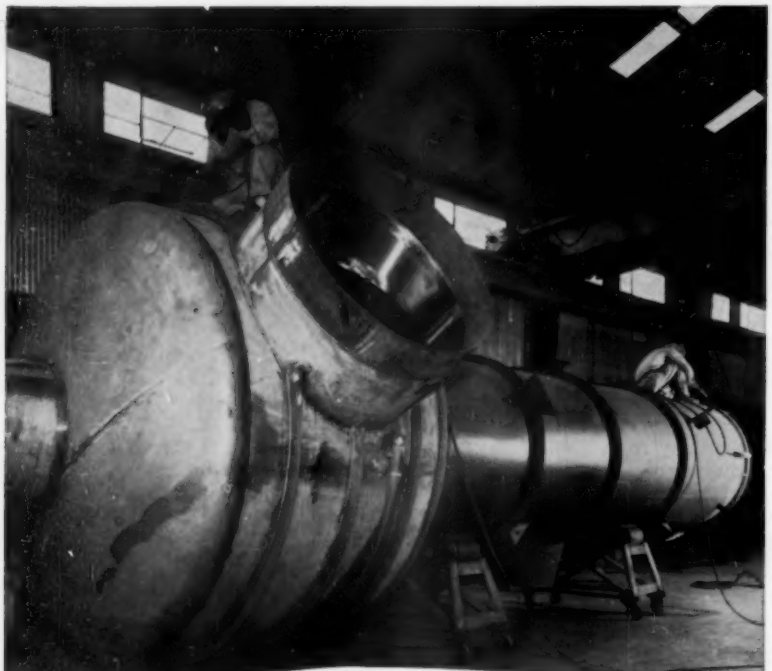
Low-Cost T-1 Type Steel

Significant savings in the fabrication of stronger, lighter steel structures and equipment are reportedly promised by a new, low-cost constructional alloy steel recently announced by U. S. Steel Corp., 525 William Penn Place, Pittsburgh 30, Pa. Designated as USS "T-1" Type A steel, the new alloy is available in quenched and tempered plates and bars ranging from $^{3}/_{16}$ to 1 in. thick inclusive.

In this thickness range, USS "T-1" Type A steel has the same 100,000-psi minimum yield strength as USS "T-1" steel introduced in 1953. Also, in thicknesses up to 1 in. inclusive, the new material and the original "T-1" steel exhibit the same degree of toughness, weldability and resistance to impact and abrasion. However, USS "T-1" Type A steel costs significantly less because of differences in chemical composition.

Plates of USS "T-1" Type A steel are available in all the widths, lengths and qualities (including flange, firebox and aircraft) currently furnished in USS "T-1" steel. If extra hardness is needed, USS "T-1" Type A can be furnished to a minimum Brinell hardness of 321.

For details, circle No. 113 on Reader Information Card.



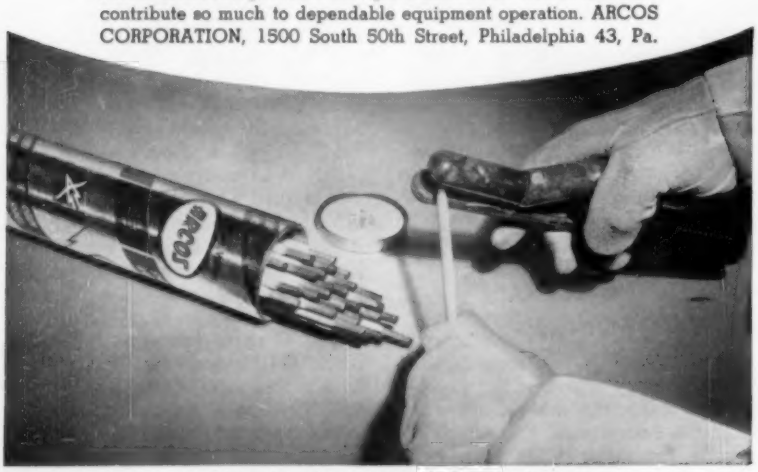
Job Report Courtesy of
Globe Fabricators, Inc., Paramount, Calif.

When stainless welds must be highly sanitary and corrosion resistant

WELD WITH ARCOS

STAINLESS ELECTRODES

Welded citrus fruit processing equipment such as this must *resist corrosion*, must *not contaminate* the food and must be *strong*. Type 304 stainless, used for all food contacting sections, was welded with Arcos Chromend K (Type 308) electrodes. For welding the non-stainless supporting members to stainless sections, Arcos Chromend HCN (Type 310) electrodes were used. Again, Arcos electrodes provided multiple benefits that cost so little and contribute so much to dependable equipment operation. ARCOS CORPORATION, 1500 South 50th Street, Philadelphia 43, Pa.



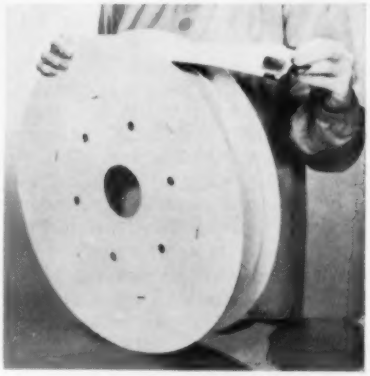
For details, circle No. 21 on Reader Information Card

New X-ray Films in Roll Form

The Industrial X-Ray Div., Eastman Kodak has announced the availability of Industrial X-Ray Film, Type AA and Type M, Ready Pack in roll form in 16, 35 and 70 mm widths. The film is wrapped in a light-tight disposable envelope.

The 35-mm rolls are used for the nondestructive testing of long pneumatic and hydrostatic tubes aircraft construction. The 70-mm film is used for testing long, welded sections of thin steel and aluminum.

The 16-mm rolls are expected to be useful for nondestructive testing



in the government's newly reactivated B-70 aircraft construction program—particularly in the inspection of brazed, stainless steel honeycomb sections.

These are all cut to length in the darkroom, and black opaque tape is placed over the ends to prevent fogging. The light-tight wrapped film is wound on 200-ft reels which have a 12-in. diam core. At the center of each flange is a 3-in. hole for spindle mounting in the darkroom so that the film can be dispensed easily.

For details, circle No. 114 on Reader Information Card.

Oxyacetylene Outfit

A new oxyacetylene outfit for light-to-medium welding and cutting has been introduced by Linde Co., Div. of Union Carbide Corp. The unit is called the Purox "Four Nines" Outfit.

Featured are dependable Purox single-stage oxygen and acetylene regulators. A lightweight welding torch with three heads for welding up to $^3/_8$ in., and a cutting attachment with one nozzle for cutting up to 2 in., are included. As furnished, the new outfit also contains $12^1/_2$ ft of oxygen and acetylene

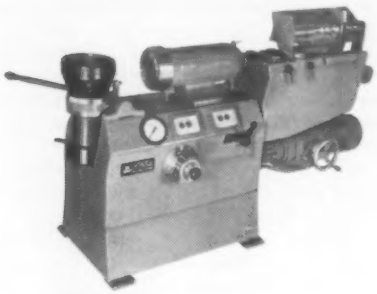
hose, friction lighter, goggles and complete operating instructions.

The outfit is packaged in a specially designed corrugated carton which serves both as a sturdy shipping container and as an eye-catching, point-of-purchase display. Integral carrying handles are also provided for convenience in transporting the unit when making sales calls.

For details, circle No. 115 on Reader Information Card.

Welding Electrode Extruder

Oerlikon Machine Tool Works, Buehrle & Co., Welding Electrode Div., Birchstrasse 230, Zurich 50, Switzerland, have developed an extruder suitable for experimental



and small production runs. The main features of this "EP 12 P-DA 3 Pv" model are a considerably larger extrusion cylinder, wire hopper and higher production speed.

The new equipment is completed by a small slug press SP 6, cross belt AB 3 and universal brushing machine BM 3.

For details, circle No. 116 on Reader Information Card.

New High-Strength Steels

Two new columbium-bearing high-strength, low-alloy steels, Armco High Strength No. 6 and No. 7, offering minimum yield points of 50,000 and 45,000 psi, respectively, have been announced by Armco Steel Corp., Middletown, Ohio. The new grades are available as plates, hot-rolled sheets and hot-rolled strip.

Corrosion resistance of these grades is equivalent to mild, non-copper bearing steels. Armco High Strength No. 6 exhibits welding properties similar to a 0.20% carbon steel while No. 7 has properties similar to a 0.10% carbon steel.

For details, circle No. 117 on Reader Information Card.

Index to Advertisers—p. 318

Job report courtesy of
Midwest Piping Co., Inc., St. Louis, Mo.

When stainless welds must pass the most rigid tests possible

USE ARCOS QUALITY FILLER METALS

This 16" diameter Type 304 stainless elbow is part of the reactor cooling system in an atomic powered ship. In welding the two halves, the first pass was made with Arcos Chromend K (Type 308) electrodes. The balance of the joint was submerged arc welded with Arcosite Bonded Flux and Chromenar K (Type 308) wire. The inset shows results of a dramatic test of the Arcos weld metal so produced. A 2½" ring, cut from an elbow, was given the normal bend test—and then completely flattened—without a crack! Such performance is the reason why Arcos is preferred for all tough jobs. ARCOS CORPORATION, 1500 South 50th Street, Philadelphia 43, Pa.

Arcos Chromend K
(Stainless) Electrodes

Arcos Chromenar K Bare Wire
and Arcosite Bonded Flux

For details, circle No. 22 on Reader Information Card

High-Pressure Regulator

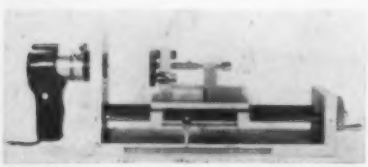
The Harris Calorific Co., Cleveland, Ohio, announces its new No. XX-87 high-pressure regulator, which has a delivery up to 2500 psi, and is provided with 4000/4000 lb gages.

This regulator was developed for use in oil refineries, chemical research laboratories and general industry, for such purposes as hydrogenation, catalytic reduction, calorimetry, accelerated age-testing and pressure testing.

For details, circle No. 118 on Reader Information Card.

Plasma Stream Calibration

A new plasma jet calibration test stand which is said to provide a simple, precise method of determining specific enthalpy and total pressure of a plasma stream is now available from Plasmadyne Corp., a subsidiary of Giannini Scientific Corp., 3839 S. Main St., Santa Ana, Calif. According to the Plasmadyne Corp., such measurements were formerly possible only with cumbersome laboratory apparatus which the user had to build and assemble himself.



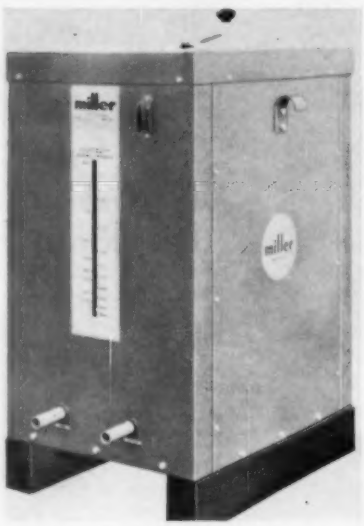
The test bench consists of a rigid plasma jet mounting stand and a variable position instrument platform. Various diameter plasma jet units can be rigidly mounted in the stand through use of special inserts. The variable position platform accommodates both measuring instruments and a material sample holder. Instrumentation available at present includes a heat flux calorimeter and a total pressure probe.

Use of the new test stand is anticipated for preliminary screening of materials in re-entry studies, and tests of hyperthermal-resistant materials used in rocket nozzle liners and nuclear reactors. Additional applications are expected in the field of high temperature chemistry.

For details, circle No. 119 on Reader Information Card.

Low-Cost Alternating Current Welding Machine

The Miller Electric Manufacturing Co., 119 N. Douglas St., Appleton, Wis., has announced the availability of model 300 and 500 amp "S" series a-c industrial welding machines at a reportedly very low selling price by foregoing "frills."



Model 500-SPa-c industrial welder

Everything necessary for top results with a-c or a-c/d-c electrodes are stated to be present; the components of this series are said to have been proved in use and are notably rugged and maintenance-free.

Movable coil design, 80 v open circuit, superior cooling, silicon steel cores, Class B insulated copper coils, dead front construction and lifetime enamel finish on heavy gage steel case are a few of the specifics claimed for this unit.

For details, circle No. 120 on Reader Information Card.

Grinding Wheel

Atlantic Abrasive Corp., South Braintree, Mass., announces the addition of a line of reinforced

resinoid depressed center disk wheels. The new line is known as Alpha and supplements the regular line of grinding wheels.

Alpha wheels are the rigid type and are made from abrasive grain and resinoid bond with triple reinforcement for greater safety, strength and durability. Designed for fast grinding action wherever quick metal removal is required, they are principally intended for use in fabricating shops for removing excess metal, beveling edges and weld grinding; and in foundries for notching and general trimming.

Alpha wheels are available in 7- and 9-in. diam—$^1/_8$, $^3/_{16}$, $^1/_4$ and $^3/_8$ in. thickness. They have a $^7/_8$-in. depressed center hole, and are manufactured in a complete range of grain size from 14 to 120.

For details, circle No. 121 on Reader Information Card.

New Power Supply with Two Weld Ranges

A 500 w-sec stored energy electronic welding power supply with a range selector switch for finer control at low settings and an automatic lockout to prevent premature discharging has been announced by the vacuum tube products division of Hughes Aircraft Co., Culver City, Colo.

The new power supply is designated the VTW-33. Its range selection switch permits the use of the full meter scale from 2 to 50 and also from 20 to 500 w-sec. Switching from one range to the other automatically discharges the energy stored, changes the meter calibration and allows the power supply to change to the new setting.

The VTW-33's $2^1/_2$ msec pulse width at 500 w-sec is reportedly the shortest weld energy discharge of any stored energy welding equipment. The VTW-33 is packaged in two vertical cabinets said to fit any standard production bench.

For details, circle No. 122 on Reader Information Card.

NOW!

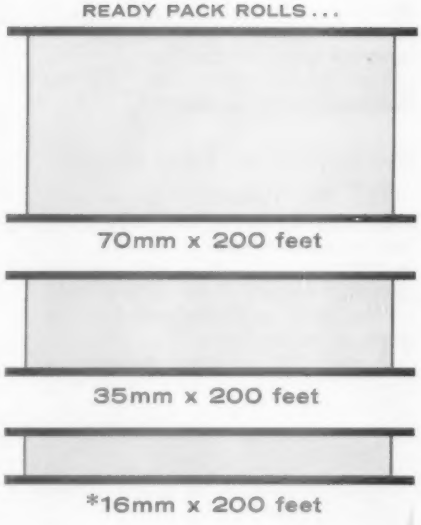
READY PACK IN ROLLS...

Kodak Industrial X-ray Film, Type AA and Type M in 16mm, 35mm and 70mm widths, 200-foot lengths

Here is America's preferred Industrial X-ray Film in a new convenient form—in 200-foot rolls, and in three widths. Ready Pack rolls are the answer for panoramic or moving slit methods of radiography of thin-wall vessels and pipe, honeycomb, circumferential welds, etc. Unroll the needed film, cut it off, seal the ends with opaque, pressure-sensitive tape. You are ready to inspect aluminum or magnesium alloys, thin steels or anything where lead screens are not required.

Ready Pack rolls are supplied on cardboard cores, 12 inches in diameter. The film is enclosed in a light-tight wrap-around sealed covering, without interleaving paper. It keeps clean and does away with darkroom loading. For processing, just separate the wrap along the sealed edge and remove the film.

For further information or to order a supply, contact your x-ray dealer or write us for a Kodak Technical Representative to call.



*For the present this size available only on a special order basis.

EASTMAN KODAK COMPANY
X-ray Sales Division, Rochester 4, N.Y.

Kodak TRADEMARK

For details, circle No. 23 on Reader Information Card

Metering Regulators

The Harris Calorific Co., 5501 Cass Ave., Cleveland, Ohio, has announced the development of a new line of metering regulators for all common gases, such as argon, helium, carbon dioxide and nitrogen as well as others.

These regulators, designated the L-40-AR series, are stated to provide sensitive control, highly important in certain industry applications, and will pass 0 to 100 cfh. They are used in industrial and laboratory pipe lines at each station where accuracy and dependability are required.

All have $^1/_4$-in. pipe thread inlets to prevent accidental mounting in high pressure cylinders. Uniformity of gas control and prevention of back pressure entering pipe is reported to be assured.

For details, circle No. 123 on Reader Information Card.

New Engine Driven Power Supplies

The Air Reduction Sales Co., 150 E. 42 St., New York 17, N. Y., has just recently marketed three new engine driven power supplies which provide rugged and dependable service while requiring only a minimum of maintenance.

A new 225 amp a-c, d-c engine driven unit—powered by a Kohler engine—can handle stick electrode welding, Heliwelding and Aircomatic welding. The power source supplies amperages from as low as 15 to 265 amp dc and 25 to 320 amp ac.

The machine is designed for jobs where dependability is essential, and can be utilized as an a-c power plant for applications other than welding.

Two new d-c diesel units are recommended for field welding where rough usage is encountered. One, the "Yellow Jacket," has been designed in 300 to 400 amp rated sizes and powered by a 4-cylinder, 4-cycle injection type diesel engine, for service on pipe line and other heavy duty construction jobs. Steady welding current is assured even when welding above the generator rating. It also features quick response to arc starts, controlled current peaks and high recovery voltage.

The third—rated at 250 amp and utilizing a 4-cycle, 3 cylinder direct injection type diesel engine—is available both as a d-c welder, a-c power plant or solely as a d-c welder. These models are recommended wherever rough usage is encountered in welding.

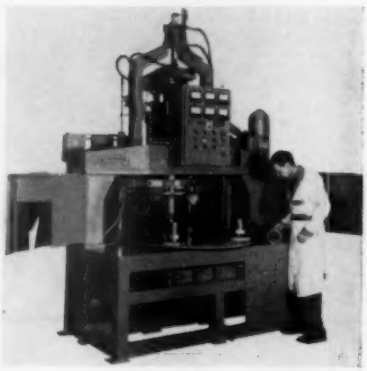
To comply with safety regulations on many jobs such as off-shore oil drilling rigs, tunnels, mines and on shipboard or wherever gasoline is prohibited, the use of diesel fuel practically eliminates the danger of fire hazard.

For details, circle No. 124 on Reader Information Card.

Rotary Index Machine for Lamination Stacks

Stacks of laminations for electric motor stators are loaded on expanding mandrels of a rotary index machine from the Taylor Winfield Corp., 1048 Mahoning Ave., Warren, Ohio, as three arc-weld torches fuse the edges of another clamped stack. Reportedly, the welder can be adjusted to automatically index the welding heads for a second pass, thus completing six lines of welds on the sides of the stators. The weld lines on outside edge of the stack thus hold the stator firmly in shape.

Lamination stacks range from 1 to 6 in. in height. Short stacks may be tandem-welded by using copper separators. Laminations are cold-rolled low-carbon steel. Dual pressure clamps are said to first flatten any shear burs, then relax to achieve proper lamination spacing. The three welding torches use tungsten electrodes and inert gas.



One hundred and fifty assemblies per hour are produced if 2-in. stacks are welded singly. By tandem stacking (with copper separators) 210 assemblies are welded each hour. It is stated that changeover of welding and clamping tooling can be completed in 5 min, enabling welding of other stator designs.

For details, circle No. 125 on Reader Information Card.

Special Spot-welding Unit

A unit said to be capable of welding stainless steel, monel and other materials as thin as one mill has been developed by Statham Instruments, Inc. 12401 W. Olympic Blvd., Los Angeles 64, Calif.

These machines, with a uniquely designed welding head, are currently being used by Statham Instruments to produce a hermetic seal weld between a thin diaphragm and frame of pressure transducers.

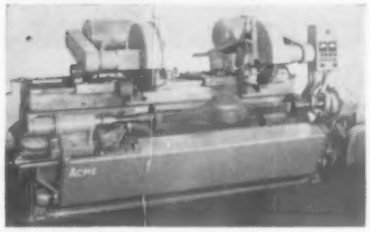
With proper power supply the welding unit is capable of from 0 to 300 spots per minute, overlapping for hermetic seal. Welding pressure can be adjusted from a few ounces to 60 lb.

For details, circle No. 126 on Reader Information Card.

Axle Housing Grinder

A new automatic axle housing grinder that grinds weld flashing from square and noncylindrical shaped axle housings is available from Acme Manufacturing Co., 1400 E. Nine Rd., Detroit 20, Mich. The machine can also be used to grind noncylindrical shafts and bars.

According to the manufacturer, the machine consists of two adjustable grinding heads mounted on a reciprocating slide and a pivoting work holding assembly with two



live centers which positions and rotates the axle housing during the grinding operation. The grinding wheels are controlled by a floating cam action that follows the contour of the axle housing. The reciprocating action of the grinding wheels insures uniform wheel wear.

The two grinding heads are powered by $7\frac{1}{2}$ hp motor. The machine occupies a floor space approximately 5 by 12 ft and is 5 ft high. An automatic timer controls the grinding cycle. Grinding time can be set from 10 sec up to 20 min, depending on the grinding application.

For details, circle No. 133 on Reader Information Card.

Brazing Torch

A new brazing torch for high-temperature brazing and overlay work, using alloy metal powders, is announced by Coast Metals, Inc., Little Ferry, N. J.

Described as exceptionally simple in both design and operation, the new torch employs a built-in aspirator to feed powdered metal into the oxyacetylene flame. Powder is drawn from a small hopper attached

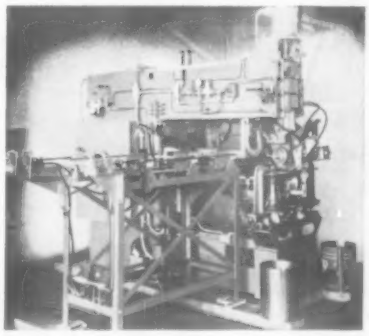
directly to the torch body. For volume work, a hose connection permits drawing powder continuously from a separate large container. Rate of powder flow is said to be easily and closely controlled by increasing or decreasing pressure on the feed control handle.

Various alloy powders for a wide range of overlay and joining applications are available for use with the torch. Included are alloys for hard facing, for general purpose brazing, for brazing stainless steels, copper, tungsten, molybdenum and other metals; as well as for use where brazed parts are subject to elevated service temperatures.

For details, circle No. 134 on Reader Information Card.

Pail Welding Machine

High production welding of standard $2\frac{1}{2}$-gal. pails is said to be possible for the first time through use of a new automatic welding machine which accommodates a range of container sizes up to 14-in. diam and 20-in. long. The machine is a side-feed type and was developed by National Electric Welding Machines Co., Bay City, Mich., to fill a container industry need for a production welder on comparatively



small runs on a variety of pail sizes. In addition to the standard $8\frac{1}{2}$-in. diam by 10-in. long $2\frac{1}{2}$-gal pail, and the 14- by 20-in. container, the machine also produces the standard 5-gal pail of $11\frac{1}{4}$-in. diam by 14-in. length.

Pails can be produced from a stock thickness range of 20 to 30 gage. The combination, "wrap-around-the-horn" welding machine reportedly has a production rate of 1500 units an hour.

The unit is powered by a 200-kva welding transformer and has phase shift heat regulation and an electronic contactor.

For details, circle No. 135 on Reader Information Card.

See The FALSTROM Controlled angle torch

AT THE WELDING SHOW
APRIL 18-20, BOOTH 711
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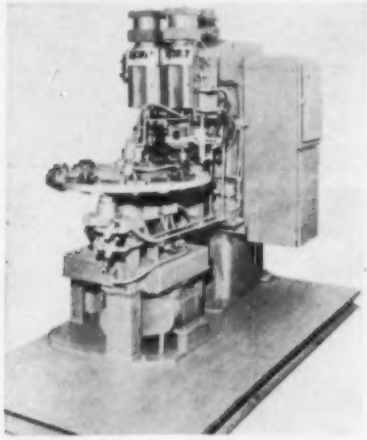
The only tungsten inert gas, arc welding torch with complete flexibility. Split-second, hand adjustment to any angle . . . to suit job requirements or your own comfort. One torch does the work of many. Model WC-180 is rated at 180 amps, AC-DC. 12½', 25' and 50' hose lengths. Low first cost . . . low maintenance. Get the facts . . . ask for Bulletin WC-60.

FALSTROM COMPANY
222 Falstrom Court
Passaic, New Jersey
PRescott 7-8018

For details, circle No. 26 on Reader Information Card

Dial Indexing Welding Machine

The Acro Welder Manufacturing Co., 1719B W. St. Paul Ave., Milwaukee 3, Wis., has recently announced a new welding machine



for manual loading and pilot production of ball bearing conveyor wheel assemblies. Two 75 kva 2300 lb electrode force press welding heads in series welding circuit projection weld two wheels. The unit includes three hopper orienting bowl and track and transfer units for automatically loading the six balls and cone and cup comprising each wheel assembly.

For details, circle No. 136 on Reader Information Card.

Machine for Tensile, Compression and Guided Bend Tests

Tensile, compression and guided bend tests can all be made on a single machine according to an announcement by Steel City Testing Machines, Inc., 8817 Lyndon Ave., Detroit 38, Mich. Motor and hydraulic power unit are located within the base of the tester, and the controls are conveniently mounted on the front. Model TE-10-AS has a capacity of 10,000 lb., and is equipped with two gages to register the load applied in two ranges. Similar machines having other capacities can be provided.

Guided bend testing, which consists of bending butt-welded samples that are originally flat into U-shapes at the welds, is performed in the compression testing area of the machine. The fixture conforms with AWS, ASME, ASTM and U. S. Government specifications. Fixtures are quickly interchangeable to permit testing butt-welded specimens of various thickness.

When used as a tensile testing machine, the lower jaw holder is placed in one of three sets of slots, to suit the specimen length.

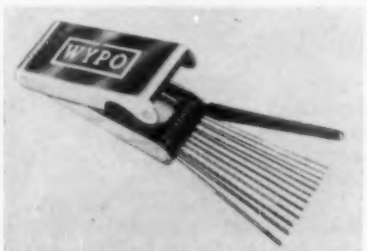
For compression testing, the guided bend fixture is replaced by a pair of hardened compression plates. The space available for compression testing will accommodate a Steel City dial-indicator type proving ring for calibrating the machine.

A feature of the machine is its compactness, with a floor space of only 14 by 24 in., an over-all height of 74 in. and a weight of about 500 lb.

For details, circle No. 137 on Reader Information Card.

Polishing File

Maitlen and Benson, Inc., Long Beach, Calif., manufacturer of Wypo cutting and welding tip cleaners, announce the inclusion of a polishing file with their stainless-steel tip-cleaner sets.



The polishing file and tip cleaners are contained in a polished aluminum case, formed to serve as a handle for the file while in use.

For details, Circle No. 138 on Reader Information Card.

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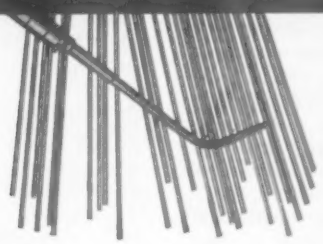
For details, circle No. 27 on Reader Information Card

TITAN quality metals for the welding industry



BRONZE WELDING RODS

Titan bronze welds are dependable in service, have high strength, toughness, excellent wear resistance. Welds are made easily and quickly to cast, malleable and wrought iron, most steels and many copper-base alloys. Because of their facility in permanent braze welding of so many metals, Titan welding rods are widely used in repair operations and in production welding of metal assemblies.

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RODS • FORGINGS • DIE CASTINGS • WELDING RODS • WIRE

Write for 6-page Welding Rod folder

For details, circle No. 24 on Reader Information Card

Extruded Leaded Alloy

A new leaded manganese bronze alloy suitable for high quality screw machine work has been introduced by Ampco Metal, Inc., 1745 S. 38th St., Milwaukee 1, Wis., producer of special wear and corrosion-resistant copper-base alloys.

The new Alloy—Ampcoloy 668—is a high-strength, free-machining material available in extruded solid and hollow bar forms. Applications for the new alloy include: bushings, bearings, gears, cams, connecting rods, valve stems, lead screw nuts, etc.

Compared to cast bearing bronzes, Ampcoloy 668 is said to offer: close extruded tolerances reduce machining scrap; no hidden porosity; greater tensile strength (75,000 psi); decreased weight (8% lighter); corrosion resistance superior to copper-tin and copper-tin-lead alloys.

Ampcoloy 668 reportedly possesses good hot working properties and can be forged if closer size tolerances and higher physical properties are required. In addition, the uniform composition, temper and lead dispersion of Ampcoloy 668 are said to permit duplication of established feeds and speeds and prevents excessive tool wear and breakage.

For details, circle No. 140 on Reader Information Card.

Flywheel Welding Machine

A new single-station automated rotary welding machine that automatically welds a ring gear to a hub in the fabrication of flywheel assemblies is now available from Expert Welding Machine Co., 17144 Mt. Elliott Ave., Detroit 12, Mich. The machine is easily adaptable to accommodate different types and sizes of flywheel assemblies through the easy interchanging of tooling.

The machine welds a gear with a $13^1/_4$ in. ID to a hub with 12 equally spaced $1^1/_8$-in. CO_2 shielded-arc weld segments at a production rate of 171 flywheel assemblies per hour at 100% efficiency. To achieve this high production rate a special continuous running cam drive is used in the machine to index the flywheel assembly through the 12 welding operations.

In operation, the ring gear and hub are manually loaded on the inclined fixture at the front of the machine. The automatic welding operation is then initiated through a push button control. At the start of the cycle, the chuck jaws and toggle clamp automatically secure the assembly in position and the overhead arm pivots down, clamps the hub and positions the welding head on the weld line. The part is then rotated through the weld sequence by the continuously running cam drive. The machine automatically stops after one revolution of the part. At the end of the automatic welding operation all clamps open and the overhead arm pivots to starting position. The completely welded assembly is then removed from the machine.

A single station automated welding machine occupies a floor space of approximately 6 by 4 ft and is 7 ft high.

For details, circle No. 139 on Reader Information Card.

Paste Oxide Remover

A paste chemical weld area cleaning compound for easy, economical removal of oxide films without pickling has been announced by the Eutectic Welding Alloys Corp., 40-40 172nd St., Flushing 58, N. Y.

Developed especially for the removal of chromium oxide "heat tint" from stainless steel, Eucleen compound is said to be also effective for removal of oxides from copper and copper alloys.

The paste is applied only to the area that needs it and will adhere to vertical surfaces or the underside of horizontal surfaces. It thus reportedly eliminates positioning, transporation to and from tanks, waste of material on areas that do not need cleaning and other problems associated with mechanical oxide removal and acid pickling.

A combination of concentrated chemicals in paste form, the compound is daubed or painted on where needed, allowed to remain for a period that depends on the base metal and surface conditions but which averages one to two minutes, then flushed off with plain water. Available in 5-, 10-, 25-, and 50-lb containers.

For details, circle No. 141 on Reader Information Card.

Automatic Spot Welding Gun

Bren Weld Corp., 5114 Third Ave., Brooklyn 20, N. Y., has announced the availability of a new patented automatic arc spot weld gun (Model 90) which welds from one side. This model is said to be

revolutionary and is amazingly simple because it is automatic. By merely pressing against the work, the arc starts and the electrode is fed automatically. When the welding operation is completed the gun shuts off and it is automatically reset and ready for the next weld.

It welds all kinds of sheet metal from a minimum 26 gage to a maximum 12 gage. The gun weighs only 2 lb and comes complete with its own power supply.

For details, circle No. 142 on Reader Information Card.

Ceramic Products

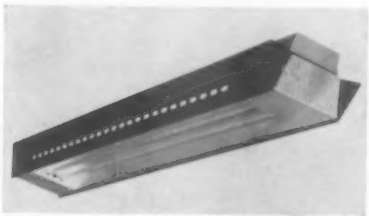
A line of ceramics, designated Duramic HT-1 series, with heat resistance to 3000° F, hardness in the range of carbides, and dielectric strength as high as 250 v per mil, is now available to industry from Duramic Products, Inc., 426 Commercial Ave., Palisades Park, N. J.

Applications include high temperature welding locators, RF heating jigs, gages, wire guides, wire drawing dies, brazing fixture components, high temperature furnace parts, nonmagnetic wear parts, chemical pump parts, semiconductor tooling, electronic insulators, welding shields, abrasive nozzles, valve sears, etc.

For details, circle No. 143 on Reader Information Card.

Infrared Heaters

A line of electric infrared heaters for welding areas has been introduced by Fostoria Corp., 1200 N. Main St., Fostoria, Pa., manufacturer of infrared equipment.



Since the heaters transfer radiant energy directly from source to object without costly heating of the intervening air, they are said to be ideal where large air movements make conventional space heating costly or ineffective; where only occasional heating is required; or for localized heating.

Designed for overhead mounting, they can be installed as easily and quickly as lighting fixtures. The new Fostoria Comfort Heaters, known as Series CH, are available in various models.

For details, circle No. 144 on Reader Information Card.

Variable Capacitor Silicon Diode

Amperex Electronic Corp., Semiconductor and Special Purpose Tube Div., 230 Duffy Ave., Hicksville, L. I., N. Y., has announced Type 1N3182 voltage variable capacitor silicon diode for automatic frequency control applications.

The 1N3182 is specifically designed and manufactured exclusively for automatic frequency control applications. Featuring a high Q (typical 60), the 1N3182 will maintain a precise oscillator frequency. The variation of capacitance with bias insures extreme sensitivity for strong oscillator pull-in.

The 1N3182 has a maximum series resistance of 3 ohms, and an average capacitance of 30 uuf with an inverse voltage of 4 volts.

For details, circle No. 145 on Reader Information Card.

New Eyeshield Design

A new and reported to be entirely different, top-quality as well as low-cost eyeshield for chipping or welding has been developed by Dockson Corp., 3839 Wabash, Detroit 8, Mich., manufacturers and distributors of a complete line of modern safety and welding equipment.

Known as the Chiporweld eyeshield, this lightweight, sturdy eye protector is said to have a roomy, one-piece, pliable, molded-plastic frame which rests lower on the face to provide the wearer with a better, broader field of vision.

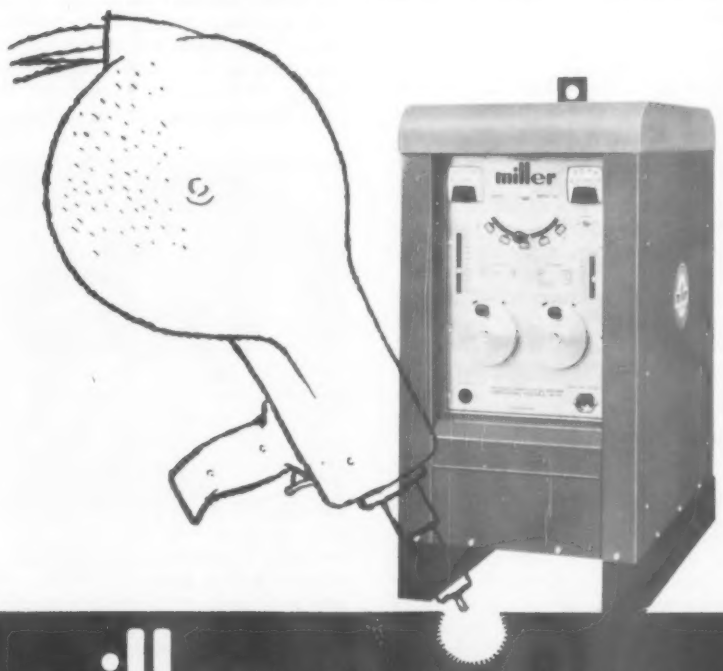
The Chiporweld eyeshield may be used with or without prescription glasses. Its new baffle design reportedly creates superior ventilation by letting air circulate freely through ample ports while preventing foreign particles and light from entering.

Clear lenses for chipping and green lenses for welding are interchangeable, and there is a plastic spacer frame between lenses to prevent fogging.

For details, circle No. 146 on Reader Information Card.

FOR **MIG** WELDING (using *any* shielding gas)

it's the Miller CP-2 VS



Swift and solid success of Miller's variable slope d-c constant potential 300 ampere welder and the 500 ampere CP-5 led to the development of the above 200 ampere version. Offered especially for use with recently introduced 200 ampere air-cooled guns having self-contained spools of wire, the CP-2 VS delivers:

Continuous voltage and slope adjustment • Current as low as 15 amps at 10 volts • A constant potential d-c source for heavy MIG work • Slope control with infinite continuous adjustment.

Information available upon request relating to 200 ampere CP-2 VS, 300 ampere CP-3 VS or 500 ampere horizontal model, the CP-5.

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Distributed in Canada by Canadian Liquid Air Co., Ltd., Montreal

For details, circle No. 28 on Reader Information Card

Dust Respirator

Glendale Optical Co. Inc., Valley Stream, N. Y., recently introduced a new all-plastic dust respirator. A main economy feature is a permanent, washable foam filter element treated with DuPont Thiuram.

Other features are: lightweight; 3-piece all-plastic design; comfortable one-size fit for all faces. The outer frame is light gray with pliable polyethylene cushion. The inner frame is said to lock the filter easily, securely into place to assure a perfect seal. Recommended for protection against nuisance dusts and for paint spraying, it is reported to be nontoxic, nonallergic.

For details, circle No. 147 on Reader Information Card.

Radiographic Inspection

Radionics Inc., Lafayette and Water Sts., Norristown, Pa., recently installed the largest cobalt 60 gamma radiography facility ever sold—containing 1430 curies of cobalt 60, or the equivalent of over $40,000,000 worth of radium. The unit, called a Gammatron, has been in use almost continuously since its installation in a room specially designed to house it at Quaker Alloy Casting Co. in Myerstown, Pa. The installation is said to be one of the safest radiography installations in the country.

Exposures which previously required hours with an 8 curie cobalt 60 source are reportedly now shot in seconds, and the new unit produces higher quality radiographs. Eight inch thick sections of steel can be radiographed in as little as 5 min. The radioactive cobalt 60 has an extremely high specific activity of 100 curies per gram, thus making for sharper radiographs.

The Gammatron is said to handle work previously requiring a 2,000,000 v X-ray machine costing more than five times as much as the cobalt 60 camera. It is used by Quaker Alloy to inspect stainless and high-alloy steel castings.

For details, circle No. 148 on Reader Information Card.

Plasma Spray Gun

A new 80 kw arc-plasma hand spray gun reported to deposit coating material over three times faster than any other portable plasma spraying device is now available from Plasmadyne Corp., 3839 S. Main St., Santa Ana, Calif.

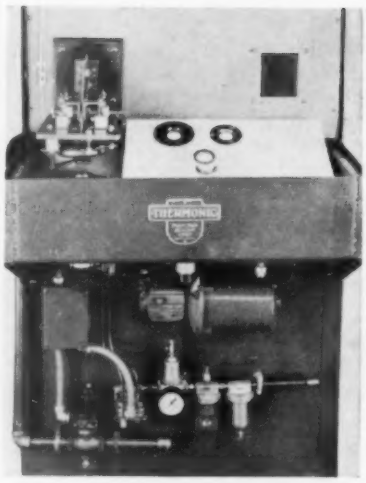
The gun's high deposition rate is expected to be a cost saving factor for job shop operations involving spray coatings of high melting point materials on interior or exterior surfaces. Zirconia, for example, is reportedly deposited with the new gun at a rate of 10 lb per hr. Corresponding rates for alumina and tungsten are said to be 12 and 20 lb per hr, respectively.

The gun weighs only 4.5 lb, has a $2^{3}/_{4}$ in. diam and is 4 in. long. Compact design enables use in constricted openings, previously considered largely inaccessible to portable plasma equipment. The gun is designed for use with standard Plasmadyne Corp., consoles and complements Plamadyne Corp. 25- and 40-kw spray guns.

For details, circle No. 149 on Reader Information Card.

Precise Hardening of Bearing Races

Induction Heating Corp., Brooklyn, N. Y., has announced the availability of equipment that is said to virtually eliminate all problems connected with the hardening of bearing races. The machine and work-coil are reportedly so precise that it is possible to heat the "working surface" to a temperature of more than 1650° F. while the metal



only 0.020 in. away remains cool enough so it will not be hardened. Moreover, power consumption is minimal; only 5 kw of rf energy are sufficient to do the delicate surface-hardening job.

The hardening job is done on a Ther-Monic Model 500 generator, with 5 kw output, and with a heating cycle of 2.2 sec. Quenching of the part takes another 2.0 sec—and the extremely precise job is done in under 5 sec.

For details, circle No. 150 on Reader Information Card.

Face Shields

A new line of face shields fitted with Fit-Rite headgear to permit easier head size and crown height adjustments is offered by Flood Safety Products Co., 3035–37 W. Lake St., Chicago 12, Ill. Crown

material of tough fiberglass is available in white, gray or yellow. All are equipped with interchangeable and replaceable windows, in either acetate, vinyl or brass screen mesh; high impact and fire resistant windows can also be furnished.

For details, circle No. 127 on Reader Information Card.

Automatic Travel Torch

The Arcair Co., P. O. Box 431, Lancaster, Ohio, announces the development of its new T-5 semi-automatic Arcair Torch. The T-5 model torch was designed to produce smooth, machine-like groove or bevel in heavy plate. Its function is gouging for weld preparation, deseaming and other similar operations. By square-butting two plates and gouging along the seam, a smooth, uniform "U" groove is produced, preparing the edge of both plates with a single operation. Smooth, straight, fast cuts can also be produced when cutting stainless steel and other special alloy plates. The T-5 model torch can be mounted on a standard cutting machine.

The T-5 melts metal with an electric arc, the molten metal being blown away with a jet of compressed air. Normal shop air pressure of 80 to 100 psi is all that is required. The torch is designed to use electrodes ranging from $^1/_4$ to $^5/_8$ in.

For details, circle No. 128 on Reader Information Card.

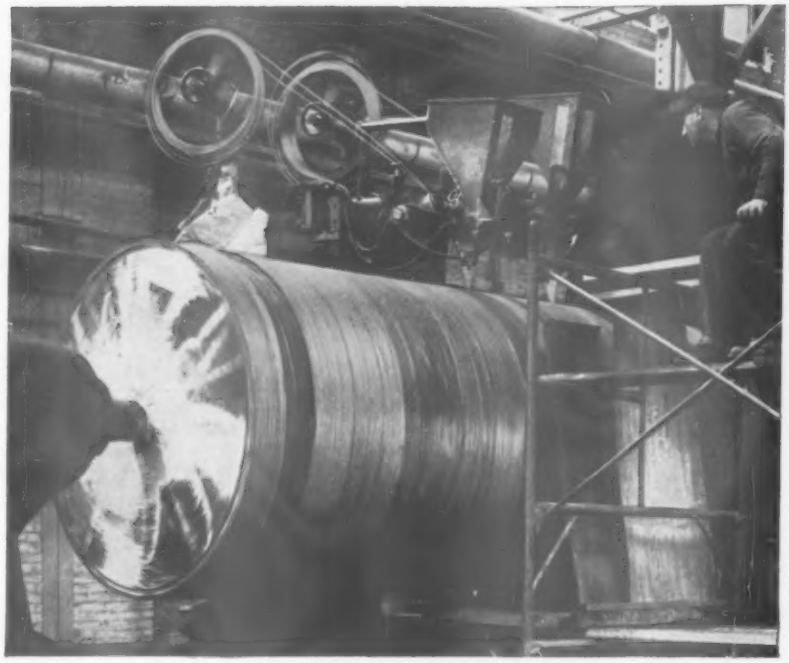
Spike Power Transistor Welder

Leak-tight fusion, great weld uniformity and smaller weld area, plus reduction of detrimental heat effect on sensitive, minute parts, are claimed for a transistor welder using the new spike power method.

Engineers at National Electric Welding Machines Co., Bay City, Mich., who applied the welding power system in converting a standard 20-kva bench press welder, have reported better welds on odd combinations of metals encountered in joining the cap and base—or header—of transistors.

Conversion is accomplished with a special transformer coupled with special spike power welding controls to produce the high peak currents that characterize the power system. Dies and other welder components remain unchanged. As before, welding is conducted in a dry box.

For details, circle No. 129 on Reader information Card.



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To protect against wear caused by sliding friction — to get years of extra service—this 7,500-ton forging-press ram was overlaid with Ampco-Trode 10 bare wire. Two submerged-arc heads were used, instead of one, to double the rate of deposit.

There are three Ampco bronze electrodes especially suited for automatic welding processes: *Ampco-Trode 10, Ampco-Trode 160,* and *Phos-Trode.* They give you a range of deposit hardnesses resistant to sliding wear, shock, squashing out, erosion, cavitation-pitting, and corrosion.

All are available also as bare and coated filler rods. Ask your Ampco distributor to recommend the Ampco-Trode that is right for you. Send coupon for bulletin. Do it today.

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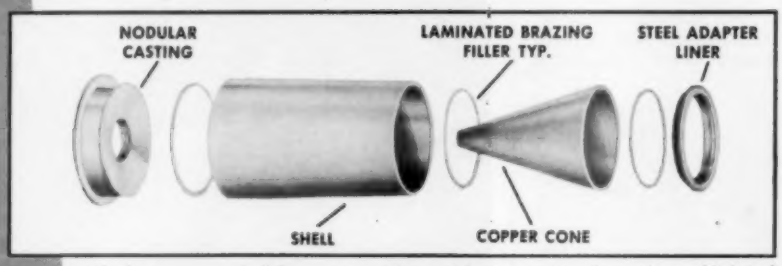

The four components of the nose assembly—nodular iron casting; low-carbon welded steel canister which measures 34" long, 15½" diameter at one end and 17¾" at the other; spun copper cone and low-carbon steel ring. The thinner rings are Easy-Flo 45 wire braided for precise alloy position and control.

Martin Develops New Induction Heating Methods to Braze Lacrosse Missile Assembly With EASY-FLO 45

One of the largest assemblies yet brazed by induction-heating techniques is a section of the Lacrosse missile being manufactured at The Martin Company's Baltimore Division. During development, one problem was posed by the variety of metals used. First it was necessary to braze a low-carbon welded steel canister and nodular iron casting. Then, to complete the assembly, a spun copper cone and low-carbon steel ring were joined to the canister. An induction coil was designed by Martin to accomplish this critical operation. Temperatures had to be restricted between 1300 and 1350°F to prevent a transformation change to the crystalline structure of the nodular iron. Martin's Materials Engineering Laboratory made careful examinations of this assembly and found that Handy & Harman Easy-Flo 45 Silver Brazing Alloy and B-1 Flux make possible the strong, uniform joints necessary to meet the stringent requirements the Company has set. Its low-working temperature, high strength, fast penetration and flow characteristics are only a few of the features which make this brazing alloy ideal.

More and more aircraft and missile components are being made with the aid of Handy & Harman silver brazing alloys and flux. The products described here are just two of the many available to help solve your problems...make your job easier and quicker. For a more complete picture of silver brazing and the advantages it offers you, write for your free copy of Bulletin 20.

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SUPPLEMENT TO THE WELDING JOURNAL, MARCH 1961

Some Factors Affecting the Notch Toughness of Steel Weld Metal

Results of investigation indicate effects of energy input, restraint and filler metal composition on notch toughness of welds in A-201 and 212 steel

BY K. E. DORSCHU AND R. D. STOUT

ABSTRACT. Considerable effort has been devoted to the development of weld metals to satisfy specific service requirements in arc welding applications. Systematic investigations involving dominant factors which control weld metal notch toughness have been limited. In the present investigation, some of these factors have been studied. In brief, some effects of welding energy input, restraint during welding and weld metal composition on the notch toughness have been investigated.

Weld metal was deposited in grooved steel plates using the submerged-arc and gas-shielded consumable-electrode processes. In the energy input study, the notch toughness of submerged-arc weld metal first decreased, then increased as the energy input was increased from 25 to 231 kilojoules per in. This trend of notch toughness was believed to be caused by the interaction of microstructural changes and variation of restraint as a result of the thermal cycles imposed on the weld metal. Because of difficulties encountered with porosity at higher energy inputs, the investigative range of gas-shielded arc energy input was limited to 19—81 kilojoules per in. In this range, the notch toughness decreased with increasing energy input. The strength and yield ratio steadily decreased as energy input was increased in both processes.

Restraint studies consisted of depositing submerged-arc weld metal in plates of varying thickness at each of four energy input levels. Increased restraint was found to cause a considerable reduction in notch toughness at lower energy inputs. Under this restraint, it is believed, a strain aging type of reaction was induced by plastic straining of the weld metal during cooling.

The effect of weld-metal composition on notch toughness was investigated using both welding processes. Site additions were made to reveal the effects of single elements over a range for each welding process. Vanadium, carbon, molybdenum, silicon and chromium reduced notch toughness of weld metal. An anomalous behavior was noted for molybdenum. Copper had little effect, and manganese and nickel were beneficial. The notch-toughness changes were similar for both welding processes.

In summary, lowering welding energy input, reducing restraint and adding nickel and manganese will be beneficial to weld-metal notch toughness. Additions of vanadium, carbon, molybdenum, chromium and silicon will decrease toughness.

K. E. DORSCHU, formerly with Dept. of Metallurgy, Lehigh University, is associated with Air Reduction Co., Inc., Central Research Laboratories, Murray Hill, N. J.; R. D. STOUT is Dean, Graduate School, Lehigh University, Bethlehem, Pa.

Paper presented at AWS Fall Meeting held in Pittsburgh, Pa., Sept. 26–29, 1960.

Introduction

As the need has increased for steels which will resist brittle failure at lower temperatures, the problem has developed to produce weld metal which will match the notch toughness of the parent material. Although progress has been made on an empirical basis, only limited studies have been conducted to determine the variables which control the notch toughness of weld metal. For example, many investigations have been undertaken to produce weld metal which would meet specific service requirements. Such investigations have filled important practical needs but have done little to determine the dominant factors influencing the notch toughness of weld metal.

Many variables, often interrelated, affect the notch toughness of weld metal. Notch toughness can vary widely according to welding procedures practiced during the deposition of weld metal.[1, 18] Variations in welding procedure cause changes in the thermal cycles which the weld metal experiences during cooling. Changes in weld-metal cooling rates can result in microstructural variations which, in turn, cause differences in notch toughness. At the same carbon

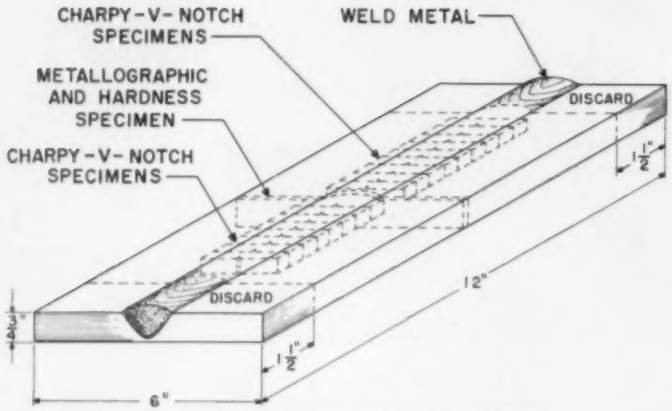

Fig. 1—Experimental base plate with deposited weld metal showing method of specimen removal

level in a pearlitic steel, for example, a decrease in ferrite grain size normally produces an increase in notch toughness.[2, 3] Such a refinement in grain size can be caused by faster cooling rates. The formation of other structures such as martensite or bainite (as a result of faster cooling rates) often produce marked changes in toughness. The type of welding process can affect the weld-metal microstructure and/or cleanliness[4] and, therefore, the notch toughness.

The response of the weld metal to the thermal cycles imposed on it depends largely on the chemical composition of the deposit. Variations in microstructures are often achieved by changing the chemical composition of the deposit using the same welding conditions. Increasing the carbon content of the steel decreases the notch toughness by increasing the relative amount of carbides in the structure.[5] Alloying elements may change toughness for a number of reasons such as hardenability variations with attendant changes in grain size and microstructure, changes in the shape and distribution of ferrite and carbides, the type of carbides, solid solution effects in ferrite and changes in eutectoid carbon content (thereby changing the relative amount of carbides in the structure). Other effects such as promotion of segregation, formation of brittle compounds and dissolved gases can also change the weld-metal notch toughness.

Restraint imposed during welding is a factor which is sometimes believed to cause embrittling effects in weld metal. A recent investigation[6] has shown restraint to have a pronounced effect on the yield ratio of steel weld metal compared to nearly unrestrained weld metal. The changes resulting from restraint were believed to be due to plastic straining of weld metal during cooling which, in turn, resulted in strain aging. It was reasoned that restraint should also have some effect on weld metal notch toughness.

Scope of Investigation

A critical examination of all of the variables cited above is obviously beyond the scope of a single investigation. It was not the purpose of this investigation to provide specific weld metal design data which could be translated directly into industrial practice. Moreover, no attempt was made to suggest a particular weld metal which would give an optimum balance of strength and notch toughness by controlling the factors mentioned in previous paragraphs.

In this investigation, some of the effects of welding energy input, restraint and weld-metal composition on the notch toughness of weld metal have been studied.

Experimental Method

All weld metal was deposited by submerged arc or gas-shielded consumable-electrode processes using reverse polarity.

For submerged arc welding, $^1/_8$-in. diam wire and a neutral calcium-silicate grade, 20 x 200 flux were used throughout the investigation. The gas-shielded-arc weld metal was deposited using $^1/_{16}$-in. diam wire with a shielding gas of argon containing 5% oxygen.

Weld metal was deposited in grooved plates measuring 6 x 12 x $^3/_4$ in. except in the restraint study where the thickness varied. A single groove was milled in the center of each plate with the groove running parallel to the 12 in. dimension.

The groove was filled with weld metal, and $1^1/_2$ in. were discarded from each end of the plate—Fig. 1. A transverse section was next removed from the center of the plate for hardness testing and metallographic examination. Standard Charpy-V-Notch specimens were machined from the top of the remainder of the plate. The notch of the impact specimens was oriented perpendicular to the plate surface and was centered in the weld deposit. In this manner, the cross section through the notch contained all weld metal. Each plate yielded approximately 17 Charpy specimens which were tested over a temperature range. The transition temperature criteria used in this investigation were based on 15 ft-lb energy absorption (notch toughness) and 15 mils expansion opposite the notch of the Charpy specimen (notch ductility).[7] Samples for chemical analyses were obtained by removing chips from the fractured surfaces of Charpy specimens using a milling cutter.

In some cases, weld metal cooling curves were obtained by immersing a chromel-alumel thermocouple in the liquid weld pool and allowing the pool to solidify around the thermocouple. The signal from the thermocouple was fed into an X-Y recorder, and cooling rates were determined from the record.

For the energy input studies, tensile specimens were removed from the weld metal. These all-weld-metal specimens were standard ASTM, 1-in. gage length (0.252-in. diam) specimens and were removed from the center of the weld deposit.

Results and Discussion

For clarity, the three major areas of study will be discussed separately. These areas are energy input, restraint and weld metal composition studies.

Energy Input Study

Submerged Arc. In order to provide a range of heat input to the weld metal, arc current ranging from 400 to 600 amp and travel speeds ranging from 5 to 25 ipm were used in the submerged-arc welding process. These variations in arc current and work travel speed produced a range of welding energy input from 25 to 231 kilojoules per inch. The base plate was $^3/_4$-in. thick A-201 steel with the groove geometry shown in Fig. 2A. The chemical composition of base plate, welding wire and weld metal are listed in Table 1, while

the welding conditions and impact properties are shown in Table 2. Strength and notch toughness of weld metal are plotted as a function of welding energy input in Fig. 3.

Inspection of Fig. 3 shows that the transition temperature increased to a maximum at approximately 120 kilojoules per inch energy input and appeared to decrease as the energy was further increased to 231 kilojoules per inch. As expected, the yield and ultimate tensile strengths decreased with increasing energy input. Elongation varied from 23 to 30%, increasing with energy input. In a similar fashion, the reduction in area increased from 56 to 68% with increasing energy input. The notch ductility (15 mils expansion) showed a similar trend to the notch toughness when considered as a function of the energy input (Table 2). The decrease in transition temperature beyond 120 kilojoules per inch, however, was not as pronounced.

An increase in welding energy input would be expected to decrease weld metal cooling rates.[8] Referring to Fig. 4, results of weld pool thermocouple immersion tests in this investigation show this to be the case. Decreasing cooling rates tended to coarsen weld metal microstructures as inspection of Figs. 5, 6 and 7 will indicate. Moreover, the refined zone between

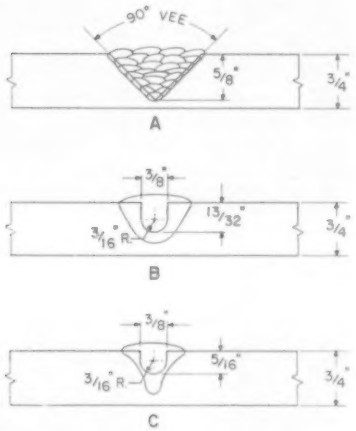

Fig. 2—Joint geometries used in experimental base plates

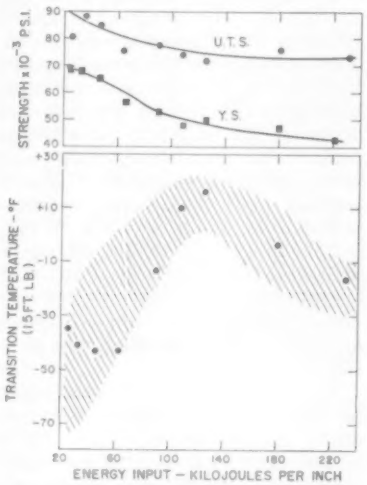

Fig. 3—Effect of energy input on notch toughness and strength of submerged arc weld metal

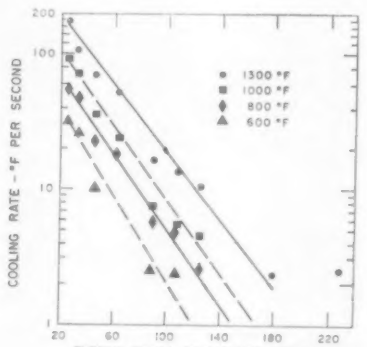

Fig. 4—Effect of energy input on cooling rates of submerged arc weld metal

Table 1—Chemical Analyses of Base Metal, Welding Wire and Submerged-arc Weld Metal

	C	Mn	Si	P	S
Base metal	0.16	0.51	0.20	0.014	0.027
Welding wire	0.12	1.96	0.05	0.010	0.022
Weld metal[a]	0.09	1.40	0.34	0.014	0.023

[a] The average weld metal composition is tabulated. Minor variations existed but were not considered to be significant.

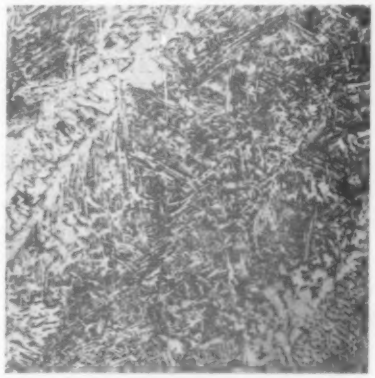

Fig. 5—Submerged arc weld metal—last pass; 25 kilojoules per inch; 1% nital etch. ×250

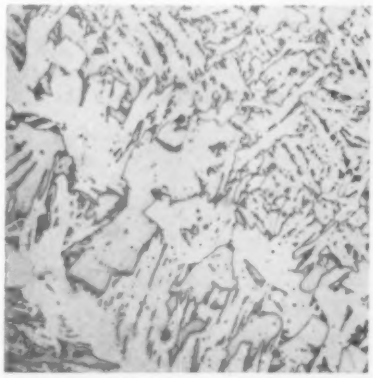

Fig. 6—Submerged arc weld metal—last pass; 108 kilojoules per inch; 1% nital etch. ×250

Fig. 7—Submerged arc weld metal—last pass; 231 kilojoules per inch; 1% nital etch. ×250

Table 2—Variation of Impact Properties with Energy Input of Submerged-arc Weld Metal

Welding energy input, kilo-joules per inch	Welding conditions: Arc current, amp	Arc voltage	Travel speed, ipm	No. passes	Impact data transition temperature, °F: 15 ft-lb	15 mils expansion
25	400	26	25	14	−35	−32
32	500	28	25	11	−42	−43
46	600	32	25	7	−43	−50
63	400	26	10	5	−37	−48
90	500	30	10	4	−13	−27
108	600	30	10	3	+10	−12
125	400	26	5	3	+16	−2
180	500	30	5	2	−3	−14
231	600	32	5	1	−16	−29

Table 3—Chemical Analyses of Base Metal, Welding Wire and Gas-shielded-arc Weld Metal

	C	Mn	Si	P	S	Al	Zr	Ti
Base metal	0.24	0.75	0.23	0.015	0.026	...	...	...
Welding wire	0.06	1.27	0.55	0.010	0.019	0.082	0.036	0.169
Weld metal[a]	0.08	0.90	0.37	0.011	0.018	0.027	0.026	0.047

[a] The average weld metal composition is tabulated. Minor variations existed but were not considered to be significant.

passes becomes coarser with increasing heat input—Figs. 8 and 9. It is generally recognized that, at the same carbon level, a coarser structure gives inferior notch toughness compared to a finer structure. The finer structure forces reinitiation of the crack more frequently when traveling through the ferrite increasing the steel toughness by the absorption of more energy. The increase in transition temperature, then, is related to an increase in ferrite grain size. Similar behavior was reported by Sagan and Campbell[18] in their work with coated electrodes. The apparent decrease in transition temperatures at still higher energy inputs, if real, may be related to a reduction in strain-induced precipitation caused by a reduction in thermal gradients at the higher input levels.[6]

Gas-shielded. In $^3/_4$-in. thick A-212 base plate with the groove geometry shown in Fig. 2A, similar tests were conducted using the gas-shielded-arc consumable-electrode welding process. A current range of 260 to 350 amp and travel speeds of 7 to 20 ipm were employed. The investigative range was limited from 19 to 81 kilojoules per inch because of excessive porosity at lower travel speeds. The composition of wire, base plate and weld metal are shown in Table 3; welding conditions and impact properties are shown in Table 4. Weld-metal strength and impact properties are plotted as a function of energy input in Fig. 10. Weld-metal cooling rates are also shown at various levels of energy input in Fig. 11.

These data indicate trends similar to those of the submerged arc study in the same energy input range—that is, toughness decreased (transition temperature increased) with increased energy input in the range investigated. Reductions in yield and tensile strength, and yield ratio were also noted with corresponding increases in energy input. The usual increase in percent elongation (from 18 to 27) and percent reduction in area (from 52 to 74) occurred with increasing energy input. Referring to Fig. 11, a similar decrease in cooling rates was noted with increased energy input and a similar grain coarsening occurred in the center of each pass of weld—Figs. 12 and 13—and between passes—Figs. 14 and 15. It should be noted that inert-gas weld metal toughness was not quite as great as submerged arc weld metal at equivalent energy inputs. Exact comparisons should not be made since the chemical

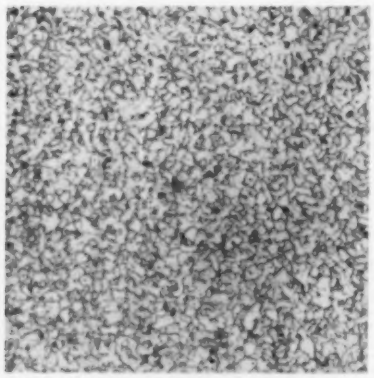

Fig. 8—Submerged arc weld metal—refined zone between passes; 25 kilojoules per inch; 1% nital etch. × 250

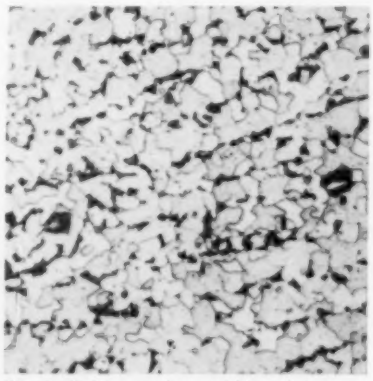

Fig. 9—Submerged arc weld metal—refined zone between passes. 108 kilojoules per inch; 1% nital etch. × 250

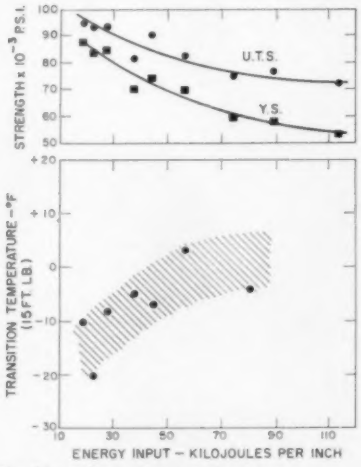

Fig. 10—Effect of energy input on notch toughness and strength of gas-shielded arc weld metal

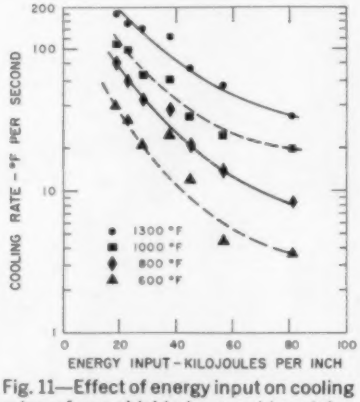

Fig. 11—Effect of energy input on cooling rates of gas-shielded arc weld metal

Table 4—Variation of Impact Properties with Energy Input of Gas-shielded Weld Metal

Welding energy input, kilojoules per inch	Welding conditions: Arc current, amp	Arc voltage	Travel speed, ipm	No. passes	Impact data transition temperature, ° F: 15 ft-lb	15 mils expansion
19	260	24	20	18	—10	—20
23	300	25	20	14	—20	—32
28	350	27	20	13	—8	—24
38	260	24	10	9	—5	—20
45	300	25	10	8	—7	—16
57	350	27	10	7	+4	—8
81	350	27	7	5	—4	—23

analyses of each deposit were not identical.

Restraint Study

To illustrate the effect of restraint, four energy input levels were selected using the submerged arc process. At each energy input, three thicknesses—$^3/_4$, $1^1/_2$ and $2^1/_2$ in.—of plate were used to deposit weld metal. The plates were sectioned from 4-in. thick plates so that the chemical composition of each plate would remain the same in all of the tests. In all cases, the groove geometry shown in Fig. 2A was used. It was thought that the thicker plate would have more of a restraining influence on the weld metal during cooling than would the thinner plate and, therefore, would give an indication of the effect of restraint on weld metal properties. The same welding wire was used as listed in Table 1, and the 4-in. thick base-plate (from which the thinner plates were sectioned) was similar in composition to the $^3/_4$-in. plate listed in the same table. The results of weld metal properties are given in Table 5, and the notch toughness is plotted as a function of energy input in Fig. 16. At the lowest energy input level, increasing the plate thickness from $^3/_4$ to $2^1/_2$ in. under identical welding conditions causes a significant increase in transition temperature. The structures were comparable and, if anything, the grain size would tend to be smaller with the increase in cooling rate accompanying the thicker plate. Thus, the increase in transition temperature at the lowest energy level could only be caused by some other factor such as restraint (probably, in turn causing strain-induced precipitation) since any corresponding increase in cooling rate would tend to lower the transition temperature by making the structure finer. The same effect can be noted at the next higher energy input level (63 kilojoules per inch). At a still higher level, however, an increase in plate thick-

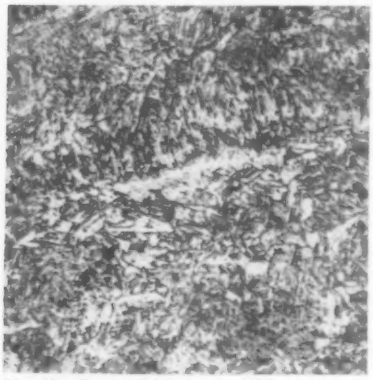

Fig. 12—Gas-shielded arc weld metal—last pass; 19 kilojoules per inch; 1% nital etch. × 250

Fig. 13—Gas-shielded arc weld metal—last pass; 81 kilojoules per inch; 1% nital etch. × 250

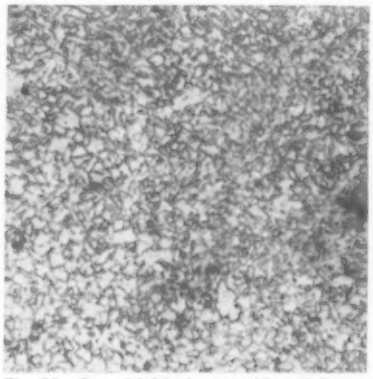

Fig. 14—Gas-shielded arc weld metal—refined zone between passes; 19 kilojoules per inch; 1% nital etch. × 250

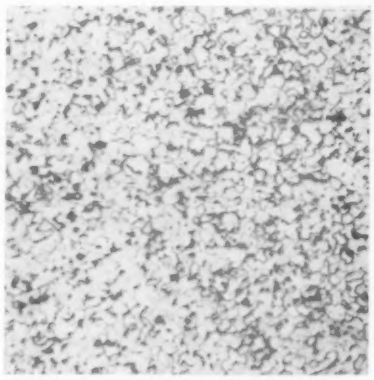

Fig. 15—Gas-shielded arc weld metal—refined zone between passes; 81 kilojoules per inch; 1% nital etch. × 250

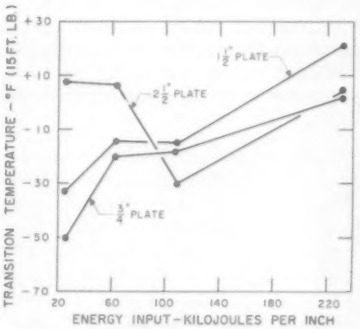

Fig. 16—Effect of plate thickness on notch toughness of submerged arc weld metal at four energy input levels

Table 5—Welding Conditions, Weld Metal Impact Properties and Hardness in the Restraint Study

Welding energy input, kilojoules per inch	Welding conditions					Impact data transition temperature, ° F		Hardness Rockwell B
	Arc current, amp	Arc voltage	Travel speed, ipm	No. passes	Plate thickness, in.	15 ft-lb	15 mils expansion	
25	400	26	25	17	$^3/_4$	−50	−60	90
25	400	26	25	17	$1^1/_2$	−33	−43	91
25	400	26	25	17	$2^1/_2$	+8	+4	92
63	400	26	10	7	$^3/_4$	−20	−33	88
63	400	26	10	7	$1^1/_2$	−14	−28	89
63	400	26	10	7	$2^1/_2$	+7	−10	90
108	600	30	10	5	$^3/_4$	−18	−25	83
108	600	30	10	5	$1^1/_2$	−15	−36	85
108	600	30	10	5	$2^1/_2$	−30	−36	87
231	600	30	5	1	$^3/_4$	+3	−10	75
231	600	30	5	1	$1^1/_2$	+22	−4	85
231	600	30	5	1	$2^1/_2$	+4	−10	88

Table 6—Welding Conditions Used in Weld Metal Composition Study

	Sub-merged arc	Gas-shielded arc
Welding energy input, kilojoules per inch	124	112
Arc current, amp	600	400
Arc voltage, volts	33	28
Travel speed, ipm	9.6	6

Table 7—Chemical Analyses of Base Metal, Welding Wire and Base Weld Metals in Weld-Metal Composition Study

	Submerged-arc			Gas-shielded-arc		
	Base metal	Welding wire[a]	Base weld metal	Base metal	Welding wire[b]	Base weld metal
C	0.16	0.10	0.12	0.16	0.09	0.12
Mn	0.47	0.41	0.60	0.47	1.27	0.70
Si	0.10	0.01	0.30	0.10	0.54	0.35
P	0.014	0.011	0.013	0.014	0.015	0.013
S	0.035	0.029	0.033	0.035	0.022	0.028
Cu	...	...	0.04	...	...	0.20

[a] Bare wire.
[b] Copper-coated wire.

ness causes a reduction in transition temperature. At this level (120 kilojoules per inch), thermal gradients (and restraint) are reduced, and an increase in plate thickness causes a finer structure and a reduction in transition temperature. Table 5 shows a similar trend for the notch ductility criterion.

An important point to note is that the severe thermal gradients existing during cooling of weld metal deposited at low heat inputs can substantially reduce toughness when the weld metal cannot relieve stresses by causing distortion in the plate. Thus, with high restraint, notch toughness improves with increased energy input.

Weld Metal Composition

To study the effect of alloying elements on the notch toughness of weld metal, site additions were made to single-pass weld deposits. Welding wires for both welding processes were chosen such that the resultant unalloyed weld metals would be essentially the same composition. In addition, the energy input for both processes was similar. The welding conditions and groove geometries used produced a fusion zone large enough to ensure that the cross section through the notch of the Charpy specimen was all weld metal.

The base plate used for both welding processes in this study was A-201 steel of the same dimensions shown in Fig. 1. The groove geometry shown in Fig. 2B was used for submerged-arc welding and that shown in 2C for gas-shielded-arc welding. After the groove was machined, site additions were weighed and evenly distributed along the groove. Then a liquid brazing cement was applied to make certain the powder site addition would stay in place during handling, and would not be moved by the inert-gas stream. This cement volatilized at 500° F and left no residue in the weld puddle. Weld metal was then deposited in the groove and specimens machined from the plate as indicated in Fig. 1.

Eight elements commonly found in weld metal were added singly to the weld deposit. The elements added were carbon, manganese, silicon, molybdenum, vanadium, nickel, chromium and copper. For each element, various amounts were added so that the notch toughness of the weld metal could be plotted as a function of the alloying element.

The welding conditions for the single-pass deposits for both the submerged arc and the gas-shielded-

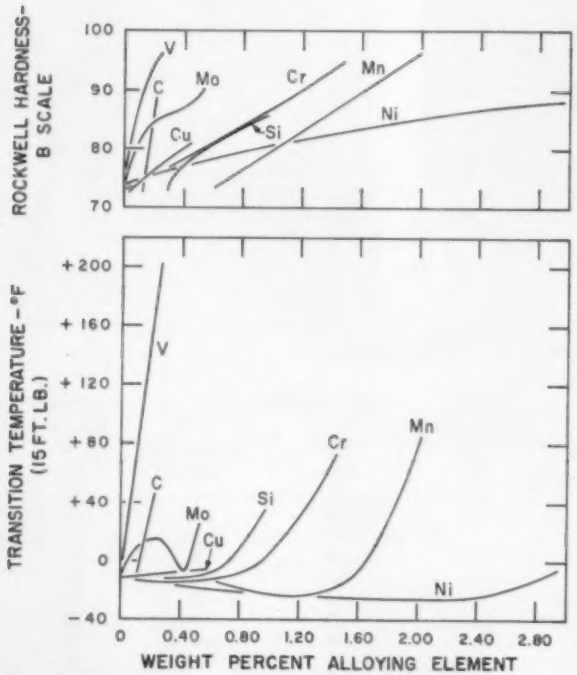

Fig. 17—Effect of alloy additions on notch toughness and hardness of submerged arc weld metal

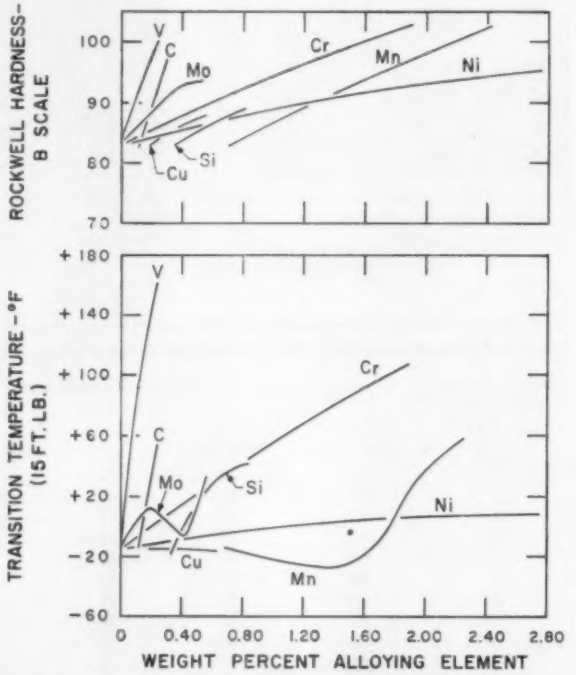

Fig. 18—Effect of alloy additions on notch toughness and hardness of gas-shielded arc weld metal

arc processes are listed in Table 6. The chemical analyses of the base plate, welding wire and unalloyed weld metal are shown in Table 7 for both welding processes. The notch toughness, notch ductility and hardness are shown for various compositions of submerged arc weld metal in Table 8 and in Table 9 for inert-gas weld metal. Summary curves of notch toughness and hardness as a function of alloy content for various elements are shown in Fig. 17 for submerged-arc weld metal and Fig. 18 for gas-shielded-arc weld metal.

Carbon. Carbon added to submerged arc or gas-shielded-arc weld metal was deleterious to notch toughness. Figures 17 and 18 indicate considerable increases in transition temperature with small increases in carbon content in weld metal. As carbon was added, a greater proportion of carbides was apparent in the structure, lowering the toughness of the weld metal. These findings are consistent with Rinebolt and Harris.[5]

Manganese. As manganese was increased from 0.60 to about 1.60%, submerged-arc weld metal showed no significant change in notch toughness—Fig. 17. Increasing manganese above 1.60% caused a rapid deterioration in toughness. The gas-shielded-arc weld metal followed a similar trend with a deterioration in toughness beyond 1.80%. Sakaki[9] noted an improvement in weld metal notch toughness in increasing manganese up to 1.1% (the maximum Mn content used), and Rinebolt and Harris[5] noted some improvement when manganese was added up to 1.5% in their study of wrought pearlitic steels. Ziegler and co-workers[10] showed some improvement in toughness up to 1.5% manganese in their study of cast carbon-manganese steels.

Hardness, as an indication of strength, increased when manganese was added. It should be noted that the hardness of inert-gas weld metal was greater than that of submerged-arc weld metal for all elemental additions at the same level. This was probably caused by the fact that the cooling rates were higher in the gas-shielded weld metal. (The structures observed were, in general, slightly finer for gas-shielded-arc weld metal, and a slightly lower energy input was used in the gas-shielded-arc process.)

Tables 8 and 9 show that the notch ductility shared the same trends as the notch toughness at various manganese levels for both processes.

Table 8—Impact Properties and Hardness of Submerged-arc Weld Metal at Various Composition Levels

Element added	Wt-% in weld metal	Impact properties transition temperature, °F		Rockwell hardness B scale
		15 ft-lb	15 mils expansion	
Base[a]	...	−12	−15	73
Mn	0.88	−20	−24	79
Mn	1.39	−22	−31	85
Mn	1.53	−12	−19	89
Mn	1.63	0	−18	91
Mn	2.02	+90	+75	96
Si	0.40	−12	−20	78
Si	0.59	−10	−10	80
Si	0.80	+12	+3	82
Si	0.96	+32	+16	86
Mo	0.14	+10	0	83
Mo	0.22	+16	+8	85
Mo	0.29	+14	+8	86
Mo	0.43	−10	−8	87
Mo	0.52	+22	+14	90
V	0.06	+31	+14	82
V	0.10	+54	+42	89
V	0.26	+200	+186	96
C	0.15	+10	−10	80
C	0.21	+42	+15	88
Ni	0.52	−18	−20	76
Ni	1.04	−18	−30	82
Ni	1.58	−28	−40	82
Ni	2.09	−20	−31	86
Ni	2.50	−22	−38	87
Ni	3.21	+14	0	89
Ni	3.26	+46	+20	92
Cr	0.49	−17	−20	81
Cr	0.98	+2	+2	84
Cr	1.48	+78	+75	94
Cu	0.19	+8	0	77
Cu	0.32	−5	−20	79
Cu	0.45	−5	−15	81

[a] The base composition is given in Table 7.

Metallographic examination revealed that the microstructure became finer with increasing amounts of manganese, i.e., the ferrite grain size decreased. In addition, more carbides were formed proportionately with increasing manganese. At higher manganese levels, the increase in transition temperature was probably caused by the formation of upper bainite which was observed at manganese levels showing a reduction in toughness.

Silicon. Silicon in amounts between 0.35 and 0.80% caused a general decrease in notch toughness in the gas-shielded-arc process. In the submerged-arc process, little change was noted up to about 0.50%, but the transition temperature increased beyond this amount. The notch ductility was essentially the same as the notch toughness. There was no significant change in the microstructure in the range investigated. These results are similar in trend to those reported by Rinebolt and Harris,[5] Sakaki[11] and Ziegler and co-workers.[12]

Molybdenum. Figures 17 and 18 show that molybdenum first appears to increase the transition temperature up to about 0.20%, decrease it in amounts up to about 0.40% and then increase it again. Although these changes in transition temperature were not great, the authors feel the trend is real in that the results were duplicated in reruns. Moreover, the same anomalous behavior was reported recently[4] in higher strength, multipass weld metal when molybdenum was added in various amounts. It should be pointed out that the net change in transition temperature from that of the base composition (0% Mo) was always an increase in transition temperature when molybdenum was added. The over-all change up to 0.50% molybdenum was not substantial. The 15 mils expansion transition temperature values were substantially the same as the 15 ft-lb values.

The reasons for this anomalous behavior are not completely understood. Molybdenum suppresses the formation of free ferrite but also increases the relative amount of carbides in the structure. Reduction of the free ferrite would

Table 9—Impact Properties and Hardness of Gas-shielded-arc Weld Metal at Various Composition Levels

Element added	Wt-% in weld metal	Impact properties transition temperature, ° F 15 ft-lb	15 mils expansion	Rockwell hardness B scale
Base[a]	...	−15	−26	83
Mn	0.93	−4	−6	85
Mn	1.16	−8	−8	85
Mn	1.52	−38	−62	92
Mn	1.78	−5	−7	94
Mn	1.96	+54	+46	99
Mn	2.37	+60	+60	102
Si	0.43	+4	−2	85
Si	0.66	+37	+20	87
Si	0.81	+37	+30	89
Mo	0.19	+12	+6	88
Mo	0.38	−4	0	93
Mo	0.41	−7	−9	...
Mo	0.48	+10	+10	92
Mo	0.57	+30	+25	94
V	0.05	+14	+10	88
V	0.10	+75	+60	91
V	0.16	+100	+90	95
V	0.18	+130	+115	96
V	0.24	+161	+160	100
C	0.17	+20	+7	87
C	0.23	+50	+30	91
C	0.27	+55	+45	94
Ni	0.43	−14	−20	86
Ni	0.79	+4	−10	86
Ni	1.27	−10	−12	90
Ni	1.60	+4	−10	91
Ni	2.69	+9	−3	95
Cr	0.58	+25	+20	89
Cr	0.88	+70	+75	92
Cr	1.28	+60	+57	96
Cr	1.84	+104	+114	102
Cu	0.35	−10	−12	86
Cu	0.50	−23	−25	87
Cu	0.65	−20	−22	87

[a] The base composition is given in Table 7.

tend to decrease the transition temperature. It may be the interaction of these two factors which produces the changes in transition temperature observed in the molybdenum additions.

Metallographic examination did not reveal the relative effect of these structural changes other than the usual effects of decreasing ferrite grain size, and increasing the proportion of carbide aggregates with increasing amounts of molybdenum.

Vanadium. Additions of vanadium up to 0.25% severely decreased the weld metal notch toughness deposited by both processes. The hardness increased rapidly with small additions of vanadium. The change in transition temperature based on the notch ductility criterion was essentially the same as that of the notch toughness. The structures observed metallographically showed some refinement in free ferrite grain size with increasing vanadium. Similar trends in notch toughness were noted by Rinebolt and Harris[5] and Ziegler and co-workers.[13]

Chromium. In general, chromium increases the transition temperature when added to gas-shielded-arc weld metal up to 1.50%. In submerged-arc weld metal, chromium does not appreciably change the transition temperature up to about 0.90% but does increase it above this chromium level. Bainite was observed in levels of chromium above approximately 1%. The notch ductility was the same as the notch toughness for both processes.

Nickel. No significant change in weld metal notch toughness was noted when nickel was added up to about 2.8% in both welding processes. Toughness was shown to increase somewhat when nickel was added to weld metal[14] and to pearlitic steels[5] by other authors.

Metallographic examination revealed a mild effect of decreasing ferrite grain size with increasing amounts of nickel.

Copper. The effect of copper in amounts up to 0.50% on weld-metal notch toughness was not significant for either welding process. No change was noted in the microstructures for copper contents up to the range cited.

Considering the general effects of the elements added on weld metal notch toughness, the most severe elements in reducing toughness were vanadium and carbon. Molybdenum showed an anomalous behavior in both processes, and silicon and chromium generally reduced notch toughness in the amounts added. Nickel and manganese showed no significant change in toughness when added up to about 2.8 and 1.6% respectively. Copper had little effect. In order of decreasing effect on hardness were vanadium, carbon, molybdenum, copper, chromium silicon, manganese and nickel for the submerged-arc process. The same order existed for gas-shielded-arc weld metal with the exception that copper had less hardening effect than chromium.

Summary and Conclusions

The results of this investigation can be summarized as follows:

1. An increase in the heat input from 25 to 231 kilojoules per inch first lowered the notch toughness of submerged arc weld metal (approximately 50° F rise at 120 kilojoules per inch) and then restored it partially. In the inert-gas process, an increase of heat input from 19 to 81 kilojoules per inch raised the transition temperature about 20° F. The losses in notch toughness were associated with coarsening of the microstructure, especially the ferrite grain size.

The slight improvement in notch toughness of the submerged-arc weld metal deposited at higher energy levels was believed to result from a reduction of strain aging caused by a reduction in restraint.

2. The hardness, tensile strength and yield to tensile strength ratio of the weld metal all decreased with increasing heat input for both the submerged-arc and the gas-shielded-arc consumable-electrode processes.

3. An increase in restraint as induced by greater plate thickness lowered the notch toughness of the weld metal considerably at lower heat inputs. This may have resulted from more severe strain-aging of the weld metal during cooling as it adjusted to the containing base metal by plastic deformation.

4. Alloying elements had a considerable effect on the notch toughness of weld metal deposited by both processes. Carbon and vanadium severely reduced notch toughness. Silicon and chromium

generally decreased notch toughness, and molybdenum showed an anomalous behavior although the over-all change was not great. Nickel and manganese showed no significant change up to about 2.8 and 1.6% respectively. Copper had little effect. It should be noted that manganese and nickel are beneficial in that increases in strength can be achieved without sacrificing reductions in notch toughness.

5. All alloying elements increased the hardness and, therefore, the strength of weld metal deposited by both processes in approximately the following order of decreasing effect: vanadium, carbon, molybdenum, chromium, copper, silicon, manganese and nickel.

Acknowledgment

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EUROPEAN WELDING RESEARCH

By Gerard E. Claussen

FRANCE

The May-June 1960 issue of *Soudage et Techniques Connexes* contains the following research:

The French Institute of Welding determined the required preheat and postheat temperatures to prevent cracking in four heat treatable aircraft steels (0.24–0.44 C, 0.8–2.8 Cr, 0.4 Mo) and five oven-baked $^1/_8$- and $^5/_{32}$-in. low-hydrogen electrodes. The controlled thermal severity test (restrained fillet) was used together with jominy curves, under-bead hardness and metallographic work. A modification of C.T.S. test for 4-in. tubes also was used. It was found that base metal cracking occurred when the weld metal was less air hardening than the base metal, but the weld metal cracked when the reverse was true. Further, preheat and postheat were effective at lower temperatures and shorter times for the weld metals that were less air hardenable and therefore more ductile.

DR. GERARD E. CLAUSSEN is associated with Arcrods Corp., Sparrows Point, Md.

EAST GERMANY

A 60-page article on arc-welding processes for cladding mild steel with austenitic stainless steel is in the June 1960 issue of *ZIS Mitteilungen* of East Germany. Cladding by welding is important for the growing East German chemical industry because rolled clad plate is difficult to obtain. The article deals principally with submerged-arc welding with a new two-electrode head and a new flux. The d-c motor driven head uses the parallel electrode principle, welding current being fed from both electrodes to the plate. The lead electrode is at an angle of 20 deg to the plate, while the trail electrode is vertical. The point of intersection of the electrode axes is 0.10 in. above plate surface at 450 amp, 30 v. A constant potential d-c generator is used. Travel speed is 20 ipm and the electrodes are 0.10 in. diam. The flux contains 26 SiO_2, 28 Al_2O_3, 24 CaO, 22 CaF_2.

The May 1960 issue of *ZIS Mitteilungen* of the East German Central Welding Institute summarizes its research on heat treatment of welded Type 321 stainless steel $^1/_2$ and $^3/_4$ in. thick. The steel contained 0.09 C, 0.56 Si, 0.98 Mn, 17.3 Cr, 10.5 Ni, 0.46 Ti, while the weld contained 0.11 C, 1.02 Si, 1.79 Mn, 18.7 Cr, 9.3 Ni, 1.0 Cb, 0.021 N. Five heat treatments were studied:

1. 25 hr at 1000° F, furnace cool
2. 10 hr at 1470° F, furnace cool
3. 2 hr at 1600° F, air cool
4. 2 hr at 1740° F, air cool
5. 2 hr at 1920° F, air cool

Measurements of ferrite and sigma contents, hardness and notch impact value showed that the best stress relieving temperature was 1740° F, and that the greatest embrittlement by sigma occurred at 1470° F, in the weld. Hot tensile and creep tests showed that treatment 5 produced the best hot ductility, but treatment 4 resulted in the highest hot yield strength. Intergranular corrosion in boiling $CuSO_4$-H_2SO_4 solution occurred only after treatment 1. The treatment caused precipitation of $Cr_{23}C_6$ in the HAZ where titanium

(*Continued on page 129-s*)

Properties of Mild Steel Weld Metal Not Revealed by the All-Weld-Metal Tensile Test

BY K. WINTERTON

SUMMARY. Present United States, Canadian and British electrode codes require the determination of mechanical properties of an all-weld-metal test piece; the deposition procedure and subsequent heat treatment are such as to favor good performance.

All-weld-metal test pieces have been made with room temperature interpass control, and without subsequent heat treatment. Satisfactory deposits were obtained from low-hydrogen electrodes (E6018), though other electrode classes (E6010, E6012 and E7024) failed to meet the ductility values specified by the codes. Moreover the deposited metal was characterized by the presence of fish eyes and high hydrogen content.

Poor ductility, perhaps made permanent by the presence of fissures, may occur in practical welded joints and the advantage in this respect of using E6018 electrodes for plated structures is emphasized.

A suggestion is also put forward for the incorporation of a more realistic test procedure in the specifications.

Introduction

There is a great deal of work[1–18] to show that for most types of metal-arc electrodes, freshly-deposited weld metal is contaminated with hydrogen, deficient in ductility, and may contain microfissures. The subject is complex, although a number of good reviews are available on hydrogen in steel[19, 20] and weld metal.[20, 21]

The amount of hydrogen present in a freshly-made weld can vary widely. In any actual welded joint or component, using a given electrode, the hydrogen level will depend chiefly on the electrode type used and on the speed with which the weld cools to room temperature. The cooling time will be determined by the mass of the component, heat input per unit time, ambient temperature or condition of preheat, and interpass temperature.

Even when the welded joint is at room temperature, the hydrogen content will slowly diminish in the course of time, being lost by diffusion. Two most important factors governing this loss by diffusion are, firstly, the ambient temperature which indirectly determines diffusivity and, secondly, the size of the welded joint or component; since this decides the extent of the free surfaces, relative to the total hydrogen content, from which the gas may escape. Even after taking these two factors into account, the rate of loss of hydrogen seems to vary considerably, which suggests that additional, unknown factors are operating. Loss of hydrogen may be accelerated deliberately by an artificial aging process by heating at temperatures in the range 200–1200° F for a controlled period, or incidentally by heat treatment applied to the component for other purposes.

Natural aging is characterized not only by loss of hydrogen from the weld metal but also by partial, and occasionally complete, realization of the inherent ductility. As might be expected, the ductility is related inversely to the hydrogen level, although the relationship is only very approximate.

Recent work by Hummitsch[18] has shown that small welded samples, made with four different electrode types, lose between 29 and 66% of their original hydrogen content over a period of 14 weeks. Improvement in ductility tended to be less regular, although showing a similar trend. In some cases, percentage elongation and reduction in area improved progressively over the same period of 14 weeks. In other cases most of the improvement occurred in the first few days, later values being erratic.

Colbus[15] also examined the changes occurring in small welded samples and also used four different electrode types. Over a period of 6 weeks the original hydrogen content was reduced by 29–66%. Over the same period the percentage elongation improved from values in the range 20–27% to values in the range 25–30%.

However, results are quoted[10] showing much smaller hydrogen losses for aging periods of 5–11 weeks, with percentage elongation improving sometimes as much as found above, sometimes improving only very slightly, and sometimes deteriorating. In periods of about a year, hydrogen content declined by 20–30%, again with erratic changes in percentage elongation.

Summarizing the results of the above work, it may be said that the hydrogen evolves sometimes rather quickly, so that most of it has disappeared after a few weeks, or it may evolve slowly so that nearly 80% of the original content is still present after 66 weeks[10] (12.65 cc/100g out of the original 16.0 cc/100g). In one instance,[10] the hydrogen content of a large multipass welded joint declined from a value of about 6.0 cc/100g to a value of 4.1 cc/100g during a period of more than 9 years.

In general, improvements in ductility, as measured by percentage elongation and reduction in area occur more quickly, often in a few weeks, although sometimes a progressive improvement may occur over much longer periods. The period of time required for any particular weld metal to attain the ductility required by specification defies accurate forecasting, since it depends on all the technical factors mentioned previously in relation to the arbitrary value of ductility assigned by the particular specification.

It should be noted that if the conditions of deposition are such that fissures are formed in the deposit, low and erratic values of percentage elongation are likely to result. Moreover, no amount of

K. WINTERTON is Head, Welding Section, Physical Metallurgy Div., Mines Branch, Dept. of Mines and Technical Surveys, Ottawa, Canada.

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natural aging can then cure the permanent damage to the ductility of the weld metal.

Little laboratory test work has been done which would imitate the adverse although not uncommon practical deposition conditions which would favor the production of fissures in the weld deposit. In some cases the initial ductility, as deposited or soon thereafter, is quite good (about 20% or higher percentage elongation). Further improvement usually then occurs with time. However, it is worth noting that when the initial ductility is low, the subsequent improvement is reduced and sometimes does not occur at all. This permanent deterioration is probably due to the presence of weld metal fissures.

Many codes[22–25] for electrodes include an all-weld-metal tension test, which is primarily required for coding the electrodes for tensile strength, but which is also supposed to give some idea of electrode quality. In such tests it is necessary to specify the deposition conditions. This is always done by selecting conditions beneficial to the properties. This is synonymous with avoiding high rates of cooling, and maintaining the temperature above ambient, during and after weld deposition.

Typical expedients are as follows:

1. Insulating the test plates from the welding table with asbestos board.[22, 23]

2. Using high interpass temperatures by: (*a*) Treating the joint in boiling water for 5 min between runs or between layers.[22, 23] (*b*) Limiting the time between runs[24] or, (*c*) using an interlayer temperature in excess of 482° F (250° C).[25]

3. "Aging" the completed sample or test pieces at elevated temperatures before testing, at 200–220° F[22] or 1112–1202° F[24] or at about 491° F.[25]

Such tests have been criticized previously for their artificiality,[2, 6, 9] although they are defended in the codes[22, 23] and elsewhere.[26]

These procedures for avoiding high rates of cooling appear less objectionable if it is made quite clear in the code that they are undertaken for the purpose of removing hydrogen[24, 25] and that the mechanical test results so obtained should not be used for design purposes.[24] Their use is sometimes defended with the contention[22] that the weld metal, by means of these artificial procedures, can be brought to a condition which it would attain in ordinary welded assemblies after a period of natural aging of 3–4 weeks duration. Such evidence as now exists does not support this contention. The present tests were undertaken in order to throw further light on the subject, in particular for electrodes presently available in Canada, and to meet the suggestion, often raised in this connection, that improvement in electrode quality renders obsolete the objections to the all-weld-metal test.

Materials

Twelve electrode brands were selected for test, representing four electrode classifications: E6010, E6012, E6018 and E7024. Representative brands of each classification were obtained from three of the major Canadian manufacturers.

A single steel plate conforming to ASTM Designation: A285 Grade C was used to make the test pieces, complying with the requirements of United States[22] and Canadian[23] specifications for mild steel arc-welding electrodes.

Test Procedure

The joint preparation was as prescribed in the United States[22] and Canadian[23] specifications—that is, 45 deg included angle single vee bevel with $^1/_2$-in. root gap and $^1/_4$-in. thick backing bar. The overall plate dimensions (6 in. × 10 in. × $^1/_2$ in. as-welded) were also in accordance with these codes. However, the butt weld was made centrally along the long direction of the plate rectangle instead of along the short length as required in these two specifications. This slight deviation could not be expected to influence the results, since the total mass of steel is constant and the joint is made unrestrained.

The joint was completed using single passes for the first two layers and, thereafter, double passes for each subsequent layer, all with $^3/_{16}$-in. diam electrodes.

The only significant departure from the terms of the United States code[22] was in the thermal treatment—that is, the deposition method and the omission of heat treatment. After each separate pass, the assembly was allowed to cool naturally in air to ambient temperature, or barely warm to the hand. All welding was done at shop temperature of around 70° F. The treatment in boiling water between passes or between layers and the final "aging" treatment (24–48 hr at 200–220° F) required by the United States code[22] were omitted.

Two series of all-weld-metal test pieces were made, one for testing after a natural aging period of 1 week and the other for testing after a natural aging period of 4 weeks. In practice, these periods were less precise, being 6–7 days and 28–30 days, respectively. The procedure adopted was dictated by the consideration that the samples should serve as much as possible of the aging time in the form of butt-welded plates and as little as possible of the aging time in the form of machined test pieces. The aging period included an allowance of one-day machining time. As soon as the machined test pieces were ready, they were either tested immediately or stored in a cold room at −50° F until they could be tested.

The tensile specimens were machined with small cylinders on each extremity so that, after removal of the lathe centers, cylinders of $^1/_4$ in. diam and $^1/_{16}$ in. length remained. These were used for duplicate hydrogen determinations and were left integral with the specimen until immediately prior to the tensile test. After removal, they were stored in liquid nitrogen, until the hydrogen determinations could be made. This was done by vacuum heating extraction at 1382° F (750° C).

Determinations of the hydrogen content of as-deposited weld metal have also been made, for each electrode. The technique has been described elsewhere.[8, 14]

Results

The results of the mechanical tests and of the hydrogen determinations are given in Table 1–3. Typical values[22] for mechanical properties

a. E6012 (Manufacturer C) b. E6010 (Manufacturer A) c. E6012 (Manufacturer A)

Fig 1—Fish eyes in E6010 and E6012 weld deposits (aged 1 week)

Table 1—Mechanical Properties of Weld Metal

Manufacturer	Class	Specification (minimum values) Ultimate tensile strength, 1000 psi	Yield point, 1000 psi	Elongation on 2 in., %	Typical (conventional test) Ultimate tensile strength 1000 psi	Yield point, psi	Elongation, %
A	E6010	62	50	22	60168	48/58	22/28
B							
C							
A	E6012	67	55	17	60/78	48/65	17/22
B							
C							
A	E6018	67	55	22	70/85	58/70	22/30
B							
C							
A	E7024	67	55	17	70/85	58/75	17/22
B							
C							

Table 2—Effect of Acid on Weld Metal

Manufacturer[a]	Aged 1 week: Ultimate tensile strength, 1000 psi	Yield point, 1000 psi	Elongation on 2 in., %	Aged 4 weeks: Ultimate tensile strength, 1000 psi	Yield point, 1000 psi	Elongation on 2 in., %	Deposit (glycerin test)
A	69.6	63.0	20	70.4	62.4	16	52
B	68.2	62.0	18	70.6	64.6	16	47
C	69.5	63.6	19	71.2	62.2	21	35
A	71.6	71.5	6	79.2	73.2	10	35
B	78.6	70.6	16	80.1	71.6	17	32
C	72.8	72.8	13	83.4	73.9	12	45
A	78.8	70.0	23	79.8	71.6	28	8
B	83.2	76.8	27	84.0	77.8	27	..
C	87.2	78.2	26	87.8	77.6	30	6
A	83.2	75.6	13	81.2	72.6	72.6	41
B	83.6	73.8	13	82.6	76.0	14	24
C	81.6	74.8	12.5	83.6	74.8	12	46

[a] Electrode classes by manufacturer remain as shown in Table 1.

Table 3—Hydrogen Content of Weld Metal

Manufacturer	Hydrogen content cc/100 gm weld metal Samples aged 1 week	4 weeks
A	8	5.5
B	9	4.5
C	9	5
A	12	15.5
B	10.5	7
C	17	17
A	0.5	0.5
B	0.5	0.5
C	0.5	0.5
A	20	22
B	29	17
C	24	36

obtainable using the conventional test (including artificial aging procedure), and the minimum specified properties[22] required are included in Table 1 for comparison.

Satisfactory ductility was obtained in the deposits from the low-hydrogen electrodes (E6018) after only one week aging. With one exception, all the other electrodes gave deposits which failed to meet the minimum elongation requirement after either 1 or 4 weeks aging. In fact, there was little if any improvement in elongation following the additional period of aging except perhaps in the deposits made with the low-hydrogen (E6018) electrodes.

It is worth noting that the yield point and ultimate tensile strength are near the upper limit or slightly in excess of the typical values obtainable when the conventional procedure is followed. There appears to be a slight tendency for yield point and ultimate tensile strength of some of the weld deposits to increase further after the additional aging period. No doubt this is due to faster cooling rates during deposition, followed by slight quench-aging. These effects are quite small.

Even after 4 weeks aging, substantial amounts of hydrogen remain in the welded deposits (except in those from the low-hydrogen electrodes) in the range 4.5–36 cc/100 g weld metal. It seems on the other hand that the low-hydrogen electrodes (E6018) not only yield reasonably low hydrogen levels in the as-welded deposits, but that the hydrogen that is produced declines very rapidly on initial aging. The hydrogen remaining in the aged samples of the E6018 deposits is so small that it may be only approximately determined.

There may be a slight tendency for the hydrogen levels to decline during the second aging period, although scatter tends to obscure the effect.

With one exception, fish eyes or haloes were found in the fractures of all the tensile specimens tested. The rutile-coated electrodes E6012 seemed to be apt to produce a large number of small fish eyes, as shown in Fig. 1a. On the other hand the cellulosic electrodes were characterized by 2 or 3 rather large fish eyes as illustrated by Fig. 1b. The iron-powder electrodes (E7024) were intermediate in this respect. The low-hydrogen (E6018) electrodes showed minute fish eyes on close examination, except in one sample. An unusual fracture appearance found in one of the E6012 deposits was thought to be due to fish-eye type defects nucleated by fissures—Fig. 1c. A similar appearance was obtained in the specimens made from the same electrode after aging for 4 weeks.

There may be a slight tendency for the fish eyes to decrease in size and number on aging, although it is difficult to confirm this in the present case with the small number of samples used.

The E6012 electrode from Manufacturer A yielded especially poor ductility values. This, combined with the peculiar fracture appearance, suggests that the tests might have been made on a faulty batch of electrodes. Two further test pieces were therefore made using these electrodes following the deposition procedure recommended by specification.[22] One of these samples was aged following the recommended procedure,[22] and for the other this treatment was omitted. The re-

Table 4—All-weld-metal Tests with E6012 Electrode from Manufacturer A

Treatment of deposit		Mechanical properties		
Interpass	Aging	Ultimate tensile strength, 1000 psi	Yield, 1000 psi	Elongation in 2 in., %
Room temperature	1 week at room temperature	71.6	71.6	6
Room temperature	4 weeks at room temperature	79.2	73.2	10
212° F (boiling water)	Omitted	80.1	68.5	13
212° F (boiling water)	23 hr at 200° F	78.4	69.0	14

sults are given in Table 4.

Although the quality of this electrode is still doubtful since the minimum elongation set by the specification was not reached, the test does illustrate the improvement that can be produced by artificial treatment. Bend tests and microscopical examination confirmed that fissures were present in the sample made from the E6012 (Manufacturer A) electrode aged for 4 weeks; further aging cannot cure permanent damage of this kind.

Conclusions

1. Weld deposits made with E6010, E6012 and E7024 electrodes, with one exception, failed to meet the minimum ductility required by specification after periods of natural aging up to four weeks; the deposits were made using a room-temperature interpass control and no subsequent artificial aging treatment was applied. Moreover, the deposits were characterized by the presence of fish eyes and high-hydrogen contents. Under the same conditions, satisfactory ductility was obtained in the deposits from E6018 electrodes.

2. Natural aging for periods of up to 4 weeks does not result in consistent improvement in the ductility of the welded deposits.

3. The room-temperature interpass used in this investigation imitates the condition that would exist with long welds on light assemblies, and the mechanical properties indicate what may be expected of such joints for the first few weeks, at least, of service. Poorer ductility may be expected for massive assemblies, and with low ambient temperatures.

4. The deposit conditions used in the conventional test procedure (high-interpass temperature) is more representative of the condition that may be obtained with short welds on light assemblies. The artificial aging treatment used in conjunction may not be equivalent to any definite period of natural aging. Certain it is that, with less favorable deposition procedures, fissuring may result in permanent damage that cannot be cured by aging, either natural or artificial.

Recommendations

1. More data should be obtained on the mechanical properties of as-deposited weld metal, for deposition conditions imitating those of practical joints and on the improvement in ductility and loss of hydrogen that occurs with time.

2. Specifications for electrodes should include the all-weld-metal test as it now exists. In addition, a similar test with less favorable deposition conditions should also be included. The results should be recorded only until sufficient data have been accumulated to specify suitable minimum requirements.

3. Low-hydrogen electrodes may be recommended for those structures presenting a danger of brittle failure, since the resultant superior ductility and absence of fissures, even under adverse deposition conditions, minimizes the danger of such failures initiating from the weld metal.

Acknowledgment

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Evaluating Crack-Resistant Electrodes for Welding HY80

BY S. I. ROBERTS

ABSTRACT: This paper is a description of one phase of developing by testing, and proving by controlled production use, the crack sensitive nature of some coated electrodes. The electrodes discussed are the iron-powder-coated type in the range of 80,000 psi yield strength of the AWS classification E-9018. This paper describes the method of selecting the electrodes most suitable for welding on HY80 steel. It also describes the method of grading, or predicting, which will be less crack sensitive or will exhibit less propensity toward cracking in production use. The theory of this test is supported by the production use of several thousand pounds of electrodes in areas where high restraint had caused considerable trouble with other types of electrodes. (NOTE: Opinions expressed in this article reflect the views of the author and do not necessarily indicate the attitude of the Navy Dept. or the Portsmouth Naval Shipyard.)

History

The performance of ship plate during World War II demonstrated, from the brittle fracture experience, the need for a higher strength material. The need was for a tougher material that would resist brittle fracture. This was especially needed when operating at lower temperature. The added requirement would be that the material would have good weldability. The HY80 steel and its commercial cousin, T-1 steel, are the result of this need.

HY80 steel is a quenched and tempered steel of high resistance to crack propagation, especially at low temperatures. Thinking in terms of fabrication, one might broadly say that this steel receives its strength from its quenched and tempered treatment in contrast to the strength from chemistry of strength steels used in the past. This obviously is an inadequate and loose description of the material under consideration here, but it is sufficient for present needs to describe this electrode development. This, being a quenched and tempered steel, requires somewhat more flexibility in one's thinking when cracking problems are encountered. A steel designed for good weldability is available as proved by many laboratory tests. Yet major problems of production use are encountered. Conditions of extremely high restraint required in the present performance of electrodes for the modern submarine has created a condition that imposes the most critical performance requirement demanded of any electrode.

The part of this quenched and tempered steel in the heat-affected zone is changed by the reheat treatment from welding. A portion may be quenched, with relative severeness, while another area may be reheat-treated quite differently. Part may have a reheat treatment quite similar to a temper, the degree depending on many factors.

With the changes in the base material from welding, coupled with the variables of fabrication shown in Fig. 1, it is understandable how the crack sensitive nature of electrodes may be exhibited differently. The purpose of variables shown in Fig. 1 is simply to illustrate the effect which some of the different factors may have on production results. The scale used is not indicative of the expected effects of each. It illustrates that each variable may have an entirely different effect when combined with other unfavorable conditions.

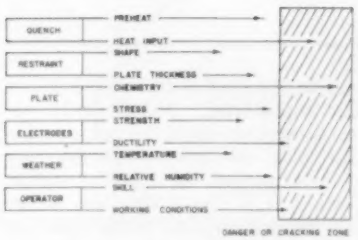

Fig. 1—Some of the variable factors and conditions that may affect weldability. (Note that arrows illustrate combining nature of several variables and are not shown for any degree of importance)

Weldability Test

Selection of a test that will predict weldability of an electrode or a steel is a problem that has confronted the engineer for many years. The factors affecting weldability are not only numerous but interrelated. Therefore, the methods used to evaluate weldability have been confronted with these difficulties. Engineers have found that to select an all-inclusive test is virtually impossible for a problem confronted with the many variables. The best test procedure, many authorities agree, should:

1. Involve actual welding.
2. Permit testing conditions approaching those of fabrication service.
3. Provide quantitative evaluation of the properties.

The Welding Research Council lists two major groups of weldability tests. One is termed a direct test and one indirect. The first test measures directly the effect of welding on steel, while the indirect test involves the evaluation of a change in some characteristic property of the weld such as microstructure of hardness, and from this information weldability may be predicted. Table 1 lists some of the divisions of direct and indirect tests.

Direct tests are further divided by the information they reveal. Thus there are bend tests, tension tests, impact and fatigue to indicate probable service performance. This information is made use of by the design engineer. The one direct test that the fabrication welding engineer is interested in is one that will predict probable troubles in fabrication.

Engineers and research personnel have developed many different kinds of weldability tests using the degree of underbead crack, the degree of restraint imposed, or involving porosity and inclusions. However, many of these tests have some serious drawbacks in grading or separating a superior operating electrode as far as cracking propensity is concerned. Yet these

S. I. ROBERTS is the Head of the Welding Engineering Branch, Portsmouth Naval Shipyard, Portsmouth, N. H.

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Table 1—Weldability Tests

Direct		
Fabrication	Service	Indirect
Underbead crack	Bend	Macro
	Tension	Metallographic
Restraint	Impact	Hardness
Porosity	Fatigue	

NOTE: The desired information should control the selection of the proper test or tests.

tests have revealed that not only different electrode types produce welds with different cracking propensity but that a difference is often displayed even between brands of the same electrode class. Therefore, our need was to develop a testing method that would predict a probable result in production welding.

Comparative Electrode Bend Test

The comparative electrode bend test was designed around the fact that it is not known why some electrodes have less propensity toward producing cracks. The purpose of this test is simply to try to predict the type that will perform better in production welding. Therefore, an attempt is made to simulate the different types of welds on one plate, using only one operator with the variables equal in relation to each other as much as possible. It was suspected that, if the average performance of the electrode showed better in the bend test, it would perform better in production welding.

Different welds are made on a plate as shown in Fig. 2. It is immaterial what type and size of welds are made on the plate if identical conditions exist in the vertical columns except for the different electrodes. An attempt is made to depict the types of welds found in production welding of the HY80 steel, although this is not at all mandatory. The purpose is to try to produce enough weaknesses that may be associated with defects in welding on this plate to predict weldability performance. The operator makes the weld in column one with a 11018 electrode, which is called standard because its use in production has established a well-known operating propensity to cracking. With same conditions, the same operator changes electrodes and puts an identical weld on the next attachment in column one—and so forth for all of the attachments in the first column. This is repeated for the remaining vertical columns. The attachments and the weld are all removed flush with the surface of the plate.

At this point, an attempt is purposely made to produce weld metal or HAZ microfissuring weakness, and then to bend the plate to produce abnormal fiber stress to reveal this or any weakness. Different electrodes do have a varying effect on the plate.

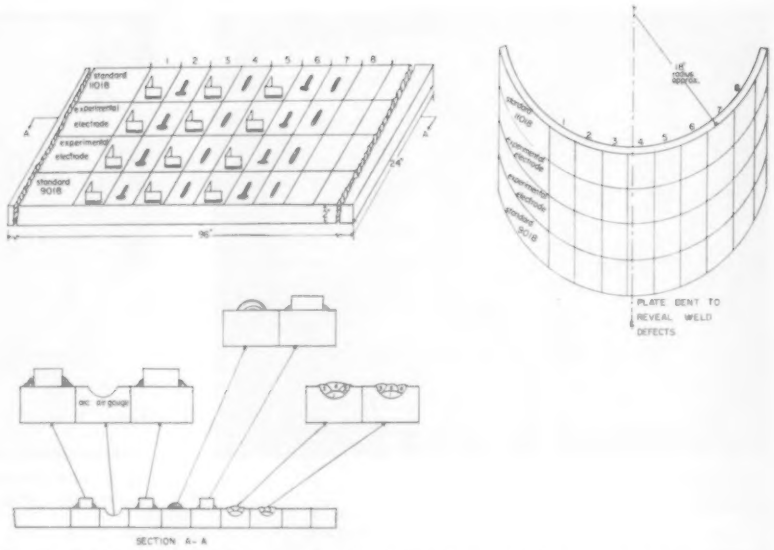


Fig. 2—Electrode comparative test wherein welds on plate are made to instill a weakness in some area of the weld or base material; weakness will be revealed when plate surface is over-stressed by bending

Evaluating Results

Upon completion of the flushing off of the attachments welded to the plate, the plate is bent as shown in Fig. 2. The approximately 18-in. radius will impose severe fiber stresses on the 2-in thick plate—stresses that are probably never encountered in fabrication use of this material. However, it is necessary to produce and reveal the weaknesses imposed by welding to obtain sufficient indications to evaluate results.

Figure 3 depicts a typical crack indicating comparison reading. Care must be exercised to record the number and severity of each crack in its true relative length.

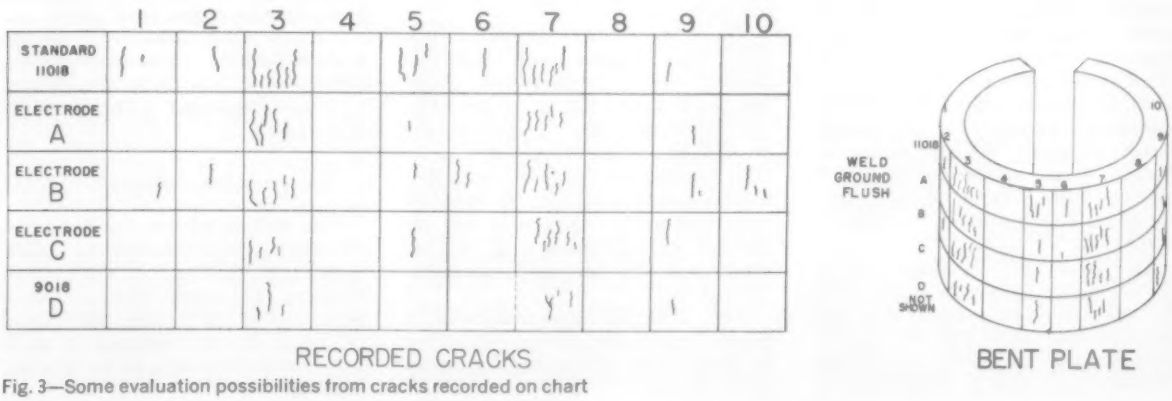


Fig. 3—Some evaluation possibilities from cracks recorded on chart

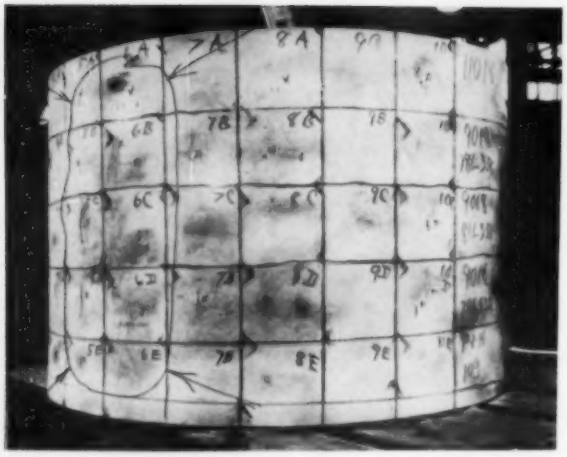


Fig. 4—Test plate after bending and magnetic particle inspection

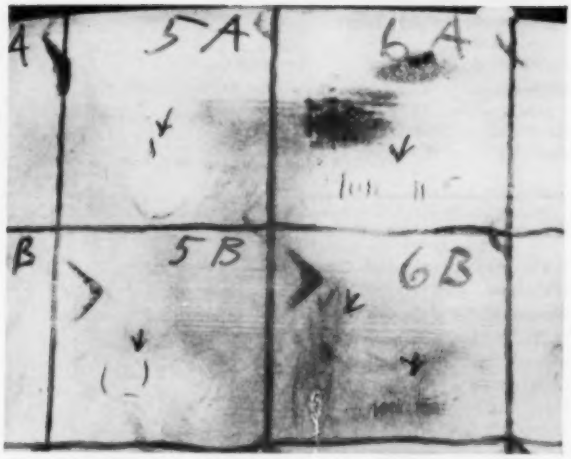


Fig. 5—Enlargement of four sections to show and record cracks

To obtain the sufficient accuracy in this, an enlarged photograph is made of the bent plate—Figs. 4 and 5. To obtain these in a true relative accuracy, the plate is painted with a white liquid penetrant developer. Then it is magnetic particle inspected, using a red Ferro powder. This enables the recorder to transcribe the actual number and lengths onto a chart shown in Fig. 3.

It is readily apparent which electrode produces the lesser weaknesses in any portion or part of the weld to HY80 base material. Sufficient welds are obtained to depict a norm of the results by visual examination of the sketch.

Production Proof

For shielded metal-arc welding of HY80, Type E11018 electrodes are used at the Portsmouth Naval Shipyard. This has produced trouble from cracking in some of the highly restrained areas in submarine construction. Several different electrodes were tested by the comparative bend test and were as sensitive to cracking as the 11018. After testing several brands, a brand "R" was found to produce superior results. In fact this was compared with Type 310 (25–20) for a comparative reading. The propensity toward cracking compared favorably to the 25–20 which, as many welding personnel realize, is an electrode that will perform with a minimum of cracking when welding many "problem" steels.

The type "R" electrode was in the strength range of Type 9018 for physical properties. For the requirements of HY80 submarine construction, this was considered sufficient strength level for use in some areas of fabrication.

An experimental order of 5000 lb was procured and used in production for noncritical, troublesome areas, such as bulkhead penetration, attachments, foundations, and similar applications. However, this electrode was not used until trouble was experienced with the 11018 type. This usually occurred in highly-stressed areas. This aspect was important as it verified the difference as revealed in comparative bend testing. It was necessary to prove beyond doubt that, if an electrode showed less damaging effect on our bend test, this would also be true in production welding.

Results were so satisfactory that permission was sought to make repairs in some of the tanks of extremely high restraint. When authority was received to make limited repairs, a close tabulation was made of cracking in highly stressed areas made with 11018 electrode. Some of these areas had cracked several times—some as many as six and seven times—without completing a final crack-free weld. The brand "R" electrode welded 30 such areas with no repeated cracking.

There are other brands which have been tested with striking results. At the present time, these are being evaluated in production use to verify the predictability of our bend test described here. It is hoped that some specific electrode characteristic can be isolated from this work and that it will be possible to determine what makes some electrodes less crack sensitive than others.

The chemical and mechanical properties of the various electrodes as supplied by the various vendors are as follows:

Chemistry	Low, %	High, %
C	0.06	0.09
Mn	0.60	1.15
P	0.009	0.02
S	0.025	0.028
Si	0.34	0.48
Mo	0.26	0.32
Ni	1.42	1.69
Physicals	**Low, psi**	**High, psi**
Yield	85,000	100,000
Tensile	99,000	106,000

Percent elongtion in 2 in.: 22–26%.
Charpy V at −60° F.: 21 to 45 ft-lb.

Conclusions

1. The comparative electrode bend test has shown that production weld characteristics can be predicted for different electrodes.
2. The test involves too much work and materials for a routine test of all electrodes.
3. The results obtained for development work could justify the cost.
4. Abnormal "punishing" type of procedures must be employed to produce enough cracks for comparison.
5. To obtain readable results in HY80 plate, the thickness must be at least $1^1/_2$ in.
6. This test might be modified to compare weldability of plate.
7. This work does not indicate that HY 80 is crack sensitive; no comparison can be made when failure to follow conclusion 4 above results in no cracks.

Acknowledgment

The author wishes to thank the electrode manufacturers for their help and advice. C. E. Cole, Welding Foreman, and the shop personnel of the Portsmouth Naval Shipyard greatly assisted in evaluating the electrodes for production welding.

Notched Longitudinal-Bend Specimens for Evaluating Armor Weldments

In tests with three covered electrodes, longitudinal-bend test proves promising for evaluating weldments in armor plate

BY S. M. SILVERSTEIN, R. P. SOPHER AND P. J. RIEPPEL

ABSTRACT. A longitudinal-bend specimen was used to evaluate the toughness performance of high-strength armor steel weldments prepared with austenitic and ferritic Grades 180 and 230 coated electrodes. A group of prime-plate specimens was prepared and evaluated for comparison purposes. A conventional longitudinal-bend specimen was modified by depositing two hard-surfacing beads on the base plate parallel to, and on each side of, the main weld joint.

Data obtained from bend testing the specimens rated the prime-plate specimens better than the weldments and rated the weldments in the following descending order: austenitic, Grade 230 and Grade 180. The transition from ductile to brittle behavior of the modified specimens occurred within 50° F of possible service temperatures, while conventional static-loaded bend specimens had to be tested at much lower temperatures to obtain this transition.

The data from the bend specimens are compared with test results of H-plates made with the same lot of base plate and with similar electrodes. This work demonstrated that the modified longitudinal-bend specimen may be used as a partial substitute for the more costly H-plate test for evaluating the toughness performance of weldments in high-strength armor steel. The rating obtained from testing the notched-bend specimens was similar to the rating obtained from ballistically testing H-plate weldments. A second reason for considering the longitudinal-bend specimen is that it can be tested in a laboratory while the ballistic testing of an H-plate requires facilities not available to most testing laboratories. A third reason for using the longitudinal-bend specimen is that the values used to determine the performance of the specimens can be measured more accurately than those of H-plates.

S. M. SILVERSTEIN is Supervisor of the Applied Research and Development Section, Materials Laboratory, Lycoming Div., AVCO Corporation, Stratford, Conn.; R. P. SOPHER is Supervisor of Research Metallurgy, Electric Boat Div., General Dynamics Corp., Groton, Conn. and P. J. RIEPPEL is Chief, Metals Joining Div., Battelle Memorial Institute, Columbus, Ohio.

Introduction

The determination of weld-joint properties for an evaluation of serviceability is as important a part of the weldability evaluation of a metal as is the determination of the welding procedure required to produce a sound welded joint in that metal.[1] For several years, the "evaluation of serviceability" specimen used for Army Ordnance armor weldments has been the ballistic H-plate. The ballistic H-plate has been an acceptable test of the fabricators' welding procedure for ordnance armor; however, this test is time consuming and expensive to prepare. Several studies[2,3] have demonstrated that H-plate tests should be conducted at subzero temperatures to predict the performance at possible service temperatures. As a result, several costly H-plates are required for a complete evaluation of armor weldments. Another disadvantage of the H-plate is that ballistic testing requires facilities not available to most testing laboratories.

The butt-welded explosion-bulge plate has been evaluated as a possible substitute or supplement to the H-plate.[2] The bulge plate was successful in evaluating weldments in Navy armor.[4] However, the bulge plate, although less expensive to prepare than the H-plate, requires facilities not available at most testing laboratories. Therefore, a laboratory test for the evaluation of serviceability of armor weldments was desired. In search for an answer to this need, an unnotched longitudinal-bend specimen was developed.[2] The specimen appeared promising as a partial substitute for the ballistic H-plate, since the longitudinal-bend specimen showed the same rating of the weldments as the ballistic H-plate. This specimen, however, had to be tested at very low temperatures to establish the ductile to brittle transition temperature and thus to show differences in the toughness of various armor weldments.

The object of this study was to develop a laboratory test which did not require extremely low testing temperatures for evaluating the toughness of armor weldments prepared with austenitic and high-strength ferritic electrodes. A special type of longitudinal-bend specimen, which contained severe stress raisers, was used. The stress raisers were notches ground in two hard-surfacing beads which were deposited on the base plate, parallel to and on either side of the weld joint. Longitudinal-bend tests containing these stress raisers were made on Army Ordnance manganese-molybdenum armor plate weldments fabricated with ferritic Grades 180 and 230 electrodes and with austenitic Type 307 electrodes. The armor was from the same lot that was used in making H-plates under a different program,[2] while the electrodes, although of similar designation, were of a different lot than those which were used for the H-plates.

Laboratory Tests

Choice of Test Specimens

The longitudinal-bend specimen was selected for study because the effects of stress concentration caused by the weld reinforcement and joint geometry are less in this type of specimen than in transverse-bend specimens. In addition, in a longitudinal-bend specimen, the weld metal, heat-affected zone and unaffected base metal are all strained

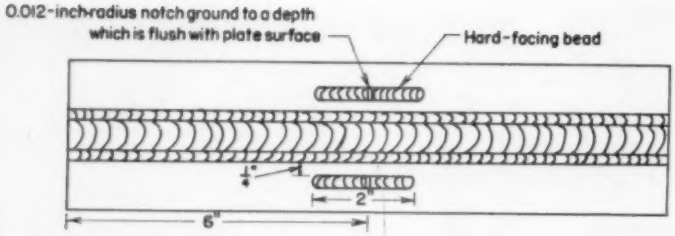


Fig. 1—Longitudinal-bend specimens showing stress raiser

approximately the same.

Previous research had shown that, when unnotched longitudinal-bend specimens[2] were used, it was necessary to conduct the bend tests at temperatures as low as −300° F to determine the temperature range in which a transition from ductile to brittle behavior occurred. In an attempt to increase the transition temperature of the weldments to a value closer to service temperatures, a stress raiser was incorporated in the longitudinal-bend specimens. A schematic diagram of this stress raiser is shown in Fig. 1.

The stress raiser consisted of two hard-surfacing beads deposited on the armor plate parallel to the longitudinal weld with notches normal to the welding direction. In this specimen, cracks initiate at the root of the ground notches in the hard-facing welds and propagate into the heat-affected base metal adjacent to the hard-surfacing bead at very low bend angles. The resulting crack fronts then serve as a source of high stress concentration (a natural crack). As the loading is increased, the cracks continue to propagate normal to the major axis of the longitudinal-bend specimen. The path of fracture was observed by applying a stain to the specimens after cracks had propagated for various distances. After staining, the specimens were bent to failure. The path of propagation of a crack through a specimen is shown in Fig. 2.

By directing the fracture transverse to the weld joint of the bend specimen, it was hoped to simulate the transverse failures that occur in H-plates. A study of ballistically tested H-plates[3] indicated that catastrophic failure generally occurred when the weld joint failed transversely. With this background of information, it was believed that the longitudinal-bend specimen might offer some promise as a substitute for the H-plate in evaluating armor weldments.

Welding Procedure

The base material used in this investigation was rolled 1-in. thick Army Ordnance homogeneous armor of the manganese-molybdenum type. This material had a yield strength of 157,000 psi, a tensile

Table 1—Chemical Analyses of Steel and Electrodes Used in Studies of 1-in. Thick Longitudinal-bend Specimens

	Composition, %			
		Electrode		
Element	Steel	Grade 180	Grade 230	Type 307
Carbon	0.25	0.12	0.06	0.13
Manganese	1.58	0.49	0.68	4.32
Silicon	0.16	...	0.42	0.51
Phosphorus	0.021	0.012	...	...
Sulfur	0.031	0.026	...	...
Molybdenum	0.45	...	0.34	...
Vanadium	0.01	...	0.18	...
Aluminum	0.003	...	...	...
Boron	0.0006	...	...	...
Nitrogen	0.008	...	...	...
Nickel	...	...	1.65	9.38
Chromium	...	...	...	19.29

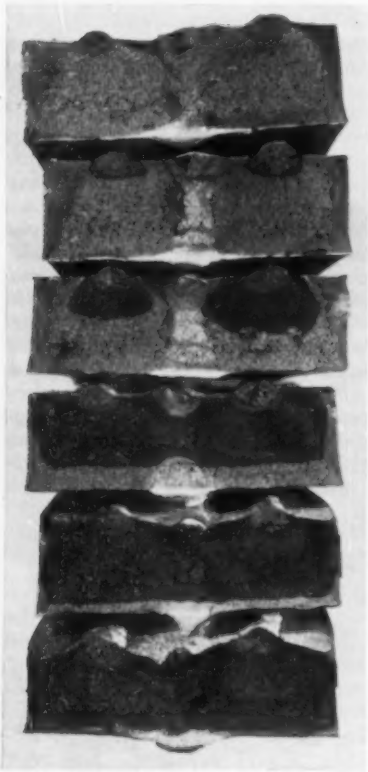
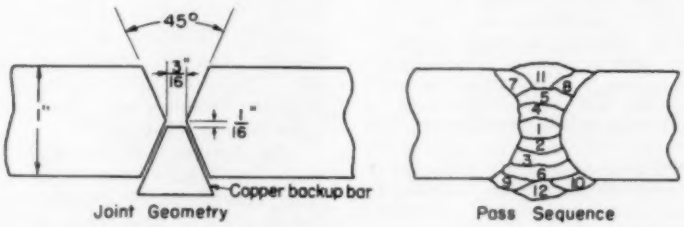


Fig. 2—Longitudinal-bend specimens showing path of crack propagation



Electrode Classification	Pass (a)	Current, amperes	Arc Voltage	Polarity	Preheat and Interpass Temperature, F
Grade 180	1	180	23	Direct-current, reverse polarity	190 to 210 all passes
	2-12	200	23		
Grade 230	1	180	23		
	2-12	200	23		
Austenitic Type 307	1-12	170	23		

(a) 3/16-inch-diameter electrodes used for all passes

Fig. 3—Details of joint, pass sequence, and welding conditions used to prepare longitudinal-bend specimens

strength of 168,000 psi and an elongation of 10% over an 8-in. gage length. The chemical analysis of the steel is given in Table 1.

The electrodes used in the study were $^{3}/_{16}$-in. diam ferritic Grade 230, ferritic Grade 180 and austenitic Type 307. The chemical compositions of weld metals deposited by these electrodes, as supplied by the manufacturer, are listed in Table 1. The ferritic electrodes conformed to Grades 180 and 230 of Specification MIL-E-986, and the austenitic electrodes, Type 307, conformed to Specification MIL-E-13080.

The joint geometry, pass sequence and welding conditions used for each type of electrode are given in Fig. 3. The plate for the test specimens was flame-beveled and grit-blasted before use. A 200° F preheat and interpass temperature was maintained for all welds. After welding, the specimens were aged in a water bath at 190 to 212° F for 48 hr to reduce the possibility of microcracks. Radiographic spot checks were made of the specimens. All the specimens checked were found to be acceptable.

A series of prime-plate specimens with the same type of stress raiser as that employed on the welded specimens was made also. The two hard-surfacing beads were deposited in the same relative location as in the welded specimens. The prime-plate specimens were made and tested for comparison purposes.

Testing Procedure

The bend-testing apparatus used in this program consisted of a loading head and an insulated box containing support rolls. The span between the support rolls was 7 in. The load was applied to the specimens at a point equidistant between the support rolls. A recess was machined into the supporting rolls and loading up to accommodate the weld reinforcement on the specimens.

The specimens were tested on a 200,000-lb capacity Baldwin Southwark Universal testing machine. The motion of the platen (relative to the stationary crosshead) was magnified and transmitted to the recording drum of the testing machine by a string and pulley arrangement. The rate of loading (platen movement) was 0.5 ipm.

The insulated box was used to contain the cooling medium in which all the specimens were immersed during testing. For test temperatures down to −100° F, the specimens were brought to the desired temperatures by immersion in a bath of dry ice and methylcyclohexane. Temperatures below −100° F were obtained by flowing liquid nitrogen through cooling coils which were immersed in methylcyclohexane.

After testing, the specimens were placed in hot water. Upon reaching room temperature, they were immersed in alcohol and then air dried. A transparent plastic coating was sprayed on the specimens to prevent rusting of the fracture surfaces.

Performance Criteria

The energy absorbed by each specimen in loading to failure was determined by measuring the area under the load-deflection curve. Typical load-deflection curves for longitudinal-bend specimens are shown in Fig. 4. Various points on the curves have been labeled as follows: "A" is the no-load value, "B" is the approximate proportional limit, "C" is the ultimate load obtained and "D" is the point of complete fracture. The curve for a specimen which exhibited a ductile failure shows a somewhat gradual decrease in load between C and D as shown by the diagram on the left side of Fig. 4.

The curve for a specimen in which there was a sudden and complete failure at maximum load after considerable deformation had occurred is shown in the center of Fig. 4. It may be seen that there was no drop in load prior to complete failure of the specimen. This curve illustrates the performance of a specimen in which there was sudden crack propagation by cleavage. No visible plastic deformation was associated with the propagation of the crack, i.e., crack propagation oc-

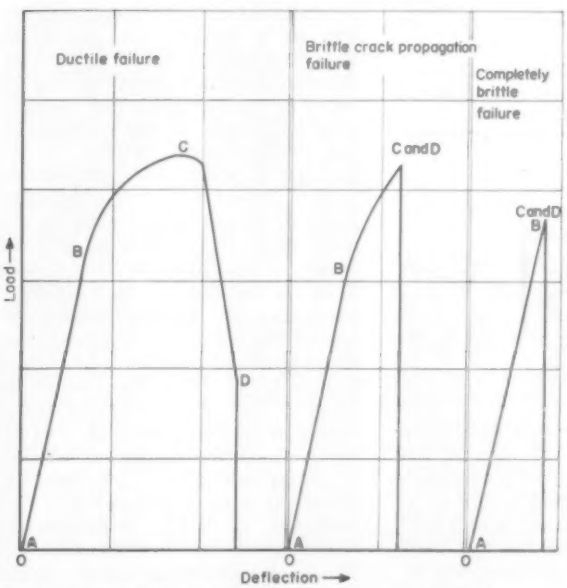


Fig. 4—Schematic load-deflection curves for longitudinal-bend specimens

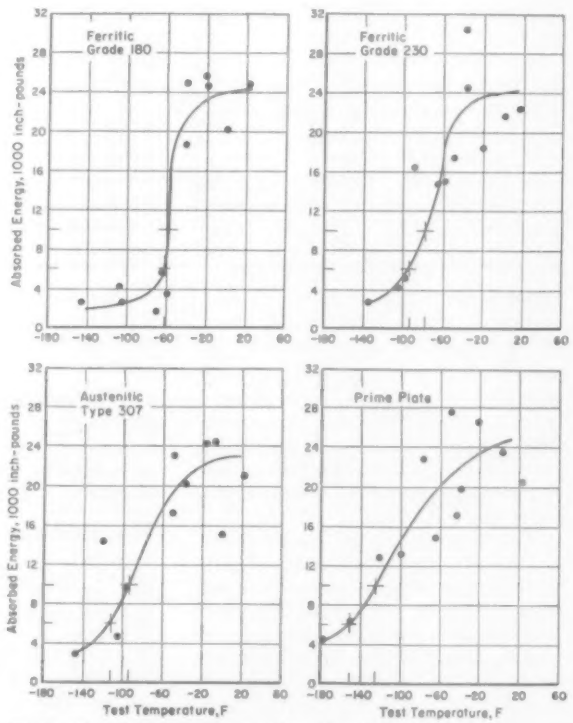


Fig. 5—Absorbed energy of notched longitudinal-bend specimens

Table 2—Longitudinal-bend Test Data and Results

Electrode	Specimen number	Test temperature, °F	Ultimate load, lb	Absorbed energy, in.-lb	Reduction in width,[a] %
Ferritic grade 180	UA 12	+21	84,700	24,800	2.26
	UA 9	−1	78,400	20,200	1.57
	UA 10	−20	83,400	24,400	2.06
	UA 8	−23	83,800	25,500	1.90
	UA 7	−42	80,000	18,600	1.43
	UA 1	−43	83,000	24,700	0.90
	UA 6	−60	50,000	3,700	0.27
	UA 11	−66	69,400	5,800	0.40
	UA 5	−72	47,000	1,800	0.13
	UA 2	−105	47,000	2,700	0.13
	UA 4	−108	64,000	4,400	0.15
	UA 3	−148	46,000	2,800	0.11
Ferritic grade 230	UB 11	+16	82,200	22,400	2.30
	UB 9	+4	82,800	21,800	2.06
	UB 8	−20	82,000	18,600	1.40
	UB 12	−35	84,400	24,600	2.16
	UB 7	−38	87,600	30,800	2.16
	UB 1	−50	84,500	17,400	0.60
	UB 5	−60	85,100	15,000	0.54
	UB 10	−64	81,800	14,700	1.13
	UB 6	−90	88,400	16,400	0.77
	UB 4	−100	70,000	5,100	0.18
	UB 2	−107	64,000	4,300	0.10
	UB 3	−136	47,700	2,800	0.05
Austenitic Type 307	UC 11	+20	79,000	21,200	1.66
	UC 9	−1	76,600	15,100	1.63
	UC 12	−10	76,800	24,500	2.40
	UC 8	−18	75,800	24,200	1.53
	UC 7	−39	79,400	20,300	1.47
	UC 4	−50	82,600	23,100	1.97
	UC 10	−53	77,000	17,200	1.56
	UC 5	−96	77,000	9,900	0.47
	UC 2	−107	65,900	4,900	0.10
	UC 6	−124	80,000	14,600	0.73
	UC 3	−148	46,600	2,600	0.18
Prime plate	BP 11	+24	84,600	20,700	1.90
	BP 9	+2	85,800	23,600	1.60
	BP 8	−23	88,300	26,600	1.73
	BP 7	−40	85,400	19,800	1.26
	BP 12	−44	82,600	17,400	1.10
	BP 6	−50	89,800	27,800	2.36
	BP 10	−66	85,000	14,900	0.83
	BP 5	−77	90,000	22,100	1.83
	BP 1	−100	87,000	13,300	1.03
	BP 2	−123	86,200	12,700	0.63
	BP 4	−150	74,000	6,500	0.20
	BP 3	−180	64,200	4,500	0.10

[a] $\frac{\text{Original-final}}{\text{Original}} \times 100$

curred during release of the elastic-strain energy in the specimen. The highest temperature producing such a failure was used in comparing the performance of the longitudinal-bend specimens.

The load-deflection curve for a completely brittle failure of a longitudinal specimen is shown on the right of Fig. 4. Because there was little separation between points B and C, it follows that there was little or no plastic deformation associated with failure. The highest temperature at which there was essentially no plastic flow prior to failure was also chosen in comparing the performance of the longitudinal-bend specimens. Below this temperature all fractures were considered to be completely brittle.

Test Results

Energy values were obtained from the load-deflection diagrams for each specimen tested. These values of energy are reported in Table 2. The test results of the welded and unwelded specimens are plotted against test temperatures in Fig. 5. It was observed (from the load-deflection diagrams) that approximately 10,000 in-lb corresponded to the highest temperature at which sudden and complete fracture occurred at maximum load after considerable plastic deformation had occurred. Therefore, the temperature corresponding to 10,000 in-lb in Fig. 5 is the highest temperature at which a brittle crack propagated (see center diagram of Fig. 4). On the basis of this criterion, the specimens were rated in the following descending order: prime plate, −130° F; austenitic Type 307, −90° F; ferritic Grade 230, −80° F; and ferritic Grade 180, −60° F.

It was observed also from the load-deflection diagrams that the 6000-in-lb energy level corresponded approximately to the highest temperature at which there was essentially no plastic flow prior to crack initiation (see right diagram in Fig. 4). The temperature corresponding to the 6000-in-lb level in Fig. 5. is the highest temperature where completely brittle failure occurred. Using this definition, the specimens were rated as follows: prime plate at −150° F, austenitic Type 307 at −110° F, Grade 230 at −90° F, and Grade 180 at −60° F.

The results of the tests showed that the transition temperature of prime-plate specimens was lower than that of welded specimens. This indicates that: (1) the butt weld and/or heat-affected zone had less resistance to the propagating crack than the prime plate, or (2) the residual stresses in the longitudinal welds caused an increase in the transition temperatures of the specimens, or both.

Percentage of reduction in width (lateral contraction) was considered also as a method for evaluating weldment performance. Lateral expansion could not be used, because many of the specimens did not fracture completely at the higher testing temperatures. A plot of reduction in width vs. absorbed energy is shown in Fig. 6. Although there is considerable scatter in the data, there appears to be a trend which is indicated by the scatter band on the graph. As mentioned previously, the highest temperature permitting brittle crack propagation corresponded with the 10,000-in-lb energy level. Therefore, from the data in Fig. 6, a value of 0.7% reduction in width could be used for determining the transition temperature for brittle crack propagation. From the data shown in Fig. 7, the criterion of 0.7% reduction in width rated the specimens in the following descending order: prime plate at −110° F, austenitic Type 307 at −80° F, Grade 230 at

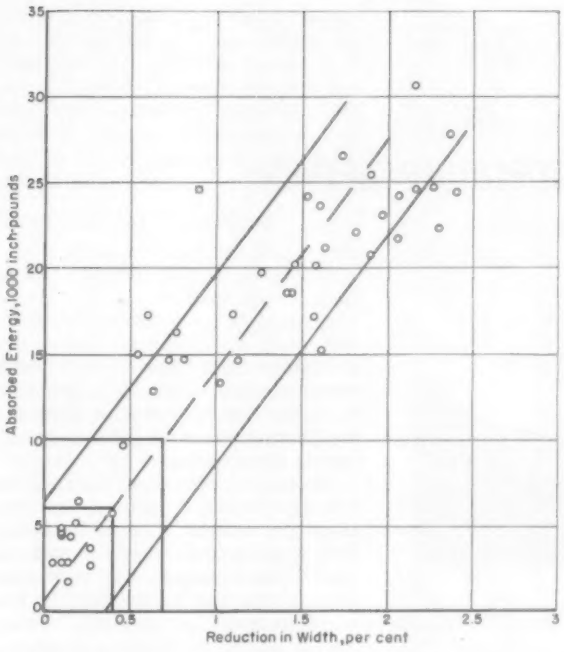


Fig. 6—Plot of absorbed energy vs. reduction in width for longitudinal-bend specimens

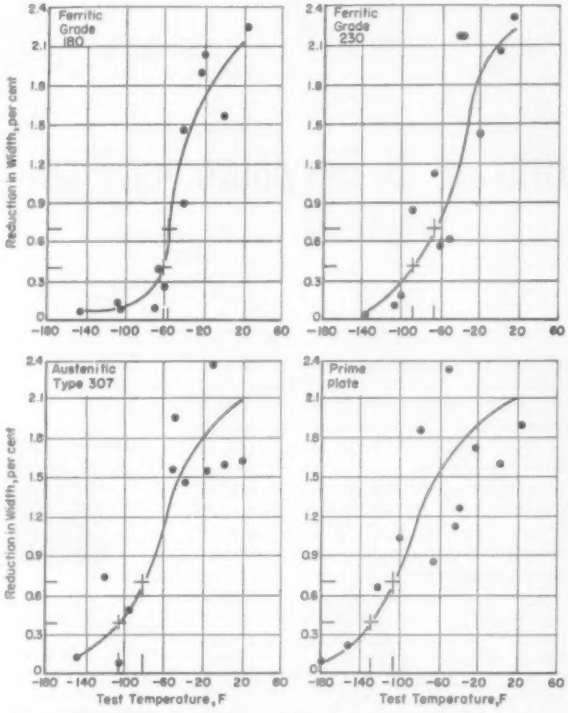


Fig. 7—Reduction in width of longitudinal-bend specimens

−70° F, and Grade 180 at −50° F. A reduction in width of 0.4% corresponded to an energy level of 6000 in.-lb as shown in Fig. 6. Using this reduction in width as a criterion for complete brittle failure, the transition temperatures of the specimens were as follows: prime plate, −130° F; austenitic Type 307, −110° F; Grade 230, −90° F; and Grade 180, −60° F

Conclusion

The stress raiser from the notched hard-surfacing weld beads was successful in increasing the transition temperature of the weldments appreciably above that obtained from unnotched bend specimens which were tested in a previous study.[2] The transition temperatures of the notched hard-surfacing bead weldments occurred within 50° F of possible service temperatures of ordnance vehicles.

The results obtained from testing the notched longitudinal-bend specimens have shown that this specimen may be used as a partial substitute for the more costly H-plate test for evaluating the toughness performance of weldments in high-strength armor steel. The ratings obtained from the bend specimens were similar to the ratings obtained from the ballistically tested H-plate weldments. The armors used in both programs were from the same lot, and the electrodes were of similar designation.

In comparing the longitudinal-bend specimen with the ballistic H-plate and the explosion-bulge plate, it was found that the bend specimen had several advantages. One advantage is that the bend specimen can be tested in almost any testing laboratory. The second advantage is that the criteria used in selecting the transition performance can be illustrated more accurately than for the other tests mentioned.

One limitation of the longitudinal-bend test is that the notched hard-surfacing beads determine the start of the fracture. In the explosion-bulge specimen and the H-plate, cracking may initiate in the most notch-sensitive component of the weldment and propagate at random. Nevertheless, most fractures in H-plates and bulge specimens propagate transverse to the weld joint at low temperatures. This mode of fracture is similar to that of the bend specimens.

The investigation of the longitudinal-bend specimen has shown that the specimen is a promising one for evaluation of weldments in armor. However, further work using this test specimen should be performed to gain a background of information which is as extensive and varied as that which exists for the ballistic H-plate.

Acknowledgments

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Brazing of Beryllium for High-Temperature Service

BY S. R. MALOOF AND J. B. COHEN

SYNOPSIS. By brazing with pure silver, joint strengths of 60% (30,000 psi) that of the base metal are obtained at room temperature. In the temperature range of 700 to 1450° F, the joint strength is 80% that of the base metal. Twenty-four hour exposures in this range of temperatures did not affect the room temperature strength, if a continuous interface of silver in the joint was absent prior to exposure.

Liquid silver spreads only partially on beryllium, apparently because of the liquid's rapid intergranular penetration. Because of this and the toxicity of beryllium fumes given off during a high-temperature braze, the silver should be preplaced or electroplated on the faces to be joined. Because of the rapid intergranular penetration of liquid silver into beryllium, elimination of the continuous interface of silver is readily accomplished by heat treatment during or after the brazing cycle. Intergranular penetration of silver into beryllium is not deleterious; a two-phase alloy consisting of beryllium primary particles surrounded by a silver matrix is ductile. Successful joints at all temperatures can in fact be made with a beryllium–20% (atomic) silver alloy, as well as with pure silver.

Introduction

The metal, beryllium, has many properties which are attractive to designers of high performance aircraft and nuclear reactors. It has a high Young's modulus, low specific gravity and low neutron-absorption cross section. The actual use of this metal has been limited by many factors. It is toxic and requires special handling facilities. At present, it is extremely brittle at room temperature, although ductility in one or two directions and, to a limited extent, in three directions can be achieved by careful control of grain orientation and size. Furthermore, fabrication techniques are not sufficiently developed so that large stock sizes can be made with reproducible properties. Research is continuing, and there is promise of eliminating some of the problems in the future or overcoming them by proper design.

S. R. MALOOF is a Group Leader in the Materials and Thermal Research Department at Avco RAD Corp., Wilmington, Mass., and J. B. COHEN was formerly Senior Scientist, Avco Corp., RAD, and is now Assistant Professor of Materials Science at the Technological Institute, Northwestern University, Evanston, Ill.

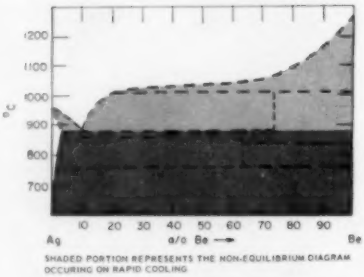


Fig. 1—The Be-Ag phase diagram[6]

One of the critical areas to be developed, if beryllium is to be used as a structural material, is that concerned with the joining of beryllium to itself and other metals for high-temperature applications. Much of the previous work on the brazing of beryllium was concerned with attaching thin beryllium windows to X-ray tubes, because of the metal's tranparency to X-rays. Vacuum-tight joints were desired in which the braze metal did not penetrate into the window to reduce this transparency; it was only necessary that the joint remain tight over the limited temperature cycle of the tube. Many alloys have been developed for this purpose.

On the other hand, there has been only limited success in developing strong brazed joints involving beryllium. Aluminum and its alloys are the only materials that have been successful for beryllium-to-beryllium brazing.[1-6] However, brazing times are long and, of course, these brazes cannot be used at high temperatures. Silver appeared promising, at least for joining beryllium to other metals for service at or near room temperature. Data on joining beryllium to itself with silver at room temperature were insufficient; only the results of one tensile test of a joint, at room temperature, were available.[1] Further work with silver seemed desirable especially in view of the success with silver for low temperatures in joining beryllium to other metals.[1]

Aluminum, silver and their alloys wet a slightly oxidized surface about as well as a clean surface.[1] This wetting and hence the spreading of these materials is slow and incomplete, and preplacing of the braze material is necessary. Pressure is helpful.[3] Wetting of aluminum and wetting time can be improved with a magnesium interlayer.[4] Although long brazing times are necessary to achieve maximum strength with aluminum and its alloys, too long a time results in reduced strength; this seems to be associated with intergranular penetration.[1] It is probable that this is a hot shortness phenomenon associated with local cracking due to solidification shrinkage during cooling.[5] Because of the brittle behavior of beryllium, it is highly notch sensitive and joint design is important. The shortest possible exposure to the brazing temperature has been preferred when using silver and its alloys to avoid the formation of intermetallic compounds between beryllium and the braze.

Failure is in general at or near the braze.[1, 2] Voids have been found in the beryllium base metal, behind the braze with certain brazing materials. It is not certain whether these occur due to the difference in diffusion rates of the braze and beryllium or are due to intermetallics unintentionally removed in polishing.[2, 3] These voids are not found in diffusion couples of beryllium with aluminum, silicon and magnesium.[4] Little is known of the phase constitution of beryllium and magnesium, but there are no intermetallics in the Be-Al and Be-Si systems. However, there is practically no solubility of these elements in beryllium so that there is no driving force for diffusion.

In the work summarized in this report, improvements in technique with pure silver were found to be

effective in producing strong joints for use up to at least 1450° F. Data are presented on design and preparation of braze materials for beryllium, wettability tests and the effect of time at temperature and structure of the joint on the strength of butt-brazed joints.

Experimental Procedure

In addition to pure silver, it was decided to try and develop braze alloys. It is difficult to decide about the interaction of beryllium with other elements, because the data on phase constitution is limited[6] and many of the commonly accepted rules of alloy formation do not seem to apply.[7] Most elements form compounds with beryllium.

It was decided to use beryllium-rich alloys. With these, the concentration gradients between the braze and base metal would be low and interdiffusion would be reduced. Also in the known systems, if the composition is chosen on the beryllium-rich side of any compound, this compound will not form at the joint interface during brazing or on exposure at elevated temperatures. A survey of the existing phase diagrams was made, keeping in mind the above goals as well as the requirement that the brazing temperature should not exceed about 1800° F, to avoid grain growth in the beryllium and the attendant destruction of texture and the mechanical properties that might be associated with it.

The beryllium-silicon system is a simple eutectic with a eutectic temperature of 1994° F. Alloys containing nominally 20% (atomic) silicon and the eutectic composition of 33% (atomic) silicon were chosen. The beryllium-silver system contains a peritectic and peritectoid compound; these might be expected to form slowly and, indeed, were not detected in initial investigations of the system.[6] With moderate cooling rates, the system appears to be a simple eutectic (Fig. 1) with a eutectic temperature of 1616° F. Beryllium-rich alloys containing nominally 10 and 20% (atomic) silver were chosen. As can be seen in Fig. 1, these alloys had one feature in addition to those mentioned above. Heat treatment above 1562° F would change the initial eutectic structure and raise the melting point to 1850° F. Consideration was given to ternary additions to these alloys. Lithium was added to some of the alloys to improve wetting and reduce oxygen transfer through the braze.[8] Lanthanum was added in an attempt to form a self-fluxing alloy.[8-10]

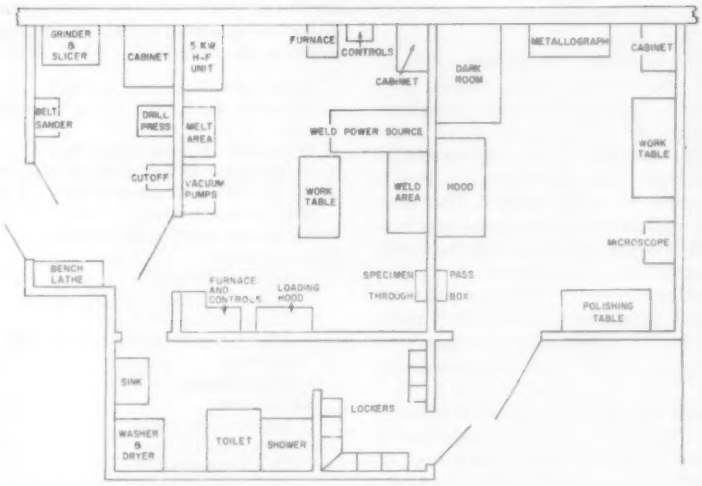


Fig. 2—Beryllium R and D area

Work was carried out in the area shown in Fig. 2. The machine shop and laboratory were entirely enclosed so that entry or exit could be made only through the washroom. (Other doors were for emergencies only.) Workers changed here on entering and leaving and showered. Entry to these rooms was by key or by an electric signal from inside the area after identification through a window or by telephone. The area was under negative pressure, with the aid of 5-in. diam flexible hoses operating at 4000 to 6000 lin fpm. These were employed to exhaust machining or fume-emitting operations. The metallographic laboratory was open to the rest of the building, but not to the beryllium area, except by a small pass box with windows in both areas. All polishing wheels were vented. The area was washed and air samples analyzed spectrographically several times a week. Weekly weight and breathing checks were given to all workers as well as thorough semi-annual physicals.

The heat source for alloy preparation, wettability studies and brazing was a 10-kw induction unit. The actual coil was inside a bell jar as shown in Fig. 3, with the surrounding venting system in case of failure. The coil could not be operated in vacuum as arcing occurred due to outgassing from the piece being heated. It was operated in an atmosphere of high-purity argon purified and dried to a dew point of −76° C in two calcium chip furnaces in the line between the tanks and the bell jar. The system was flushed and evacuated prior to any operation. During heating, the vacuum pump and gas line were operated simultaneously to maintain a pressure of about 800 microns.

For melting alloys, a beryllia crucible or alumina crucible and graphite susceptor were used. Beryllium chunk was placed at the bottom of the crucible with the heavier elements on top. Ingots about $^{3}/_{4}$-in. long with a $^{5}/_{8}$-in. diam after cropping were inverted, cut up and remelted at least once; additional remelting was done if chemical analysis indicated appreciable segregation.

For wettability studies, $^{1}/_{4}$ x $^{1}/_{4}$ x $^{1}/_{16}$-in. beryllium sheets were placed on a recessed steel rod in the coil. The recess was oxidized, and a Pt-Pt 10% Rh thermocouple connected to a recorder was placed in a hole 0.01 in. below the center of the beryllium sample. It was calibrated from the known melting point of silver during a wettability test. All tests were made at 100 to 200° F

Fig. 3—The induction heating apparatus

above the melting point of the metal or alloy.

For brazing operations, 0.3-in. diam beryllium rods were machined. They had larger diameters at one end where they were supported in seats in a molybdenum fixture so that there was a space between two such rods. This was filled with silver foil; pressure was applied to the joint during the brazing cycle by the expansion of the beryllium and a small weight of several grams on top of the rods. A Pt-Pt 10% Rh thermocouple was placed near the joint to record the cycle.

Butt joints were also obtained by heat treating silver-plated beryllium pieces held in molybdenum or tungsten fixtures (to apply pressure by differential expansion of the fixture and beryllium pieces). The plating procedure is presented in Table 1. The heat treatment was carried out in a furnace, which could be evacuated or filled with a gas; this was a three-zone furnace wound with wire of an iron-chromium-aluminum alloy.

Tensile bars were machined from the joined rods. The test sections were hand polished, and the threaded ends were etched with "beryllium bright dip" consisting of 450-ml H_3PO_4, $26^1/_3$ ml H_2SO_4, $53^1/_4$ g chromic anhydride at 235 to 240° F.

Metallographic and radiographic techniques were employed throughout the work to examine the nature of the joint between the beryllium and braze metal. The most suitable metallographic procedures were found to be:

1. Pure Be: An attack polish with a 10% oxalic acid–alumina slurry on hard silk was followed by an attack polish with equal parts of beryllium-bright dip and water added slowly to a stiff-napped cloth of rayon containing alumina abrasive of a particle size less than 0.1 micron. Polarized light revealed the greatest detail.

Table 1—Procedure for Electroplating Silver on Beryllium

1. Rinse with demineralized H_2O.
2. Immerse for 1 min in concentrated HNO_3 (70 to 80° F).
3. Rinse with demineralized H_2O.
4. Immerse for 45 sec in $(NH_4)_2SO_4$ (70 to 80° F)—100 g/l; lower Ph to 2.0 with H_2SO_4, balance H_2O.
5. Rinse with demineralized H_2O.
6. Silver strike
   AgCN—0.75 oz/gal
   KCN—9.0 oz/gal
   Temperature—R.T.
   C.D.—Steady evolution of gas at cathode
   Time—30 sec
7. Silver plate
   AgCN—12.0 oz/gal
   KCN—14.5 oz/gal
   Temperature—100° F.
   C.D.—20 amp/sq ft
   Time—228 sec for 5 microns of silver
8. Cold H_2O rinse.
9. Hot H_2O rinse.

2. With Be and Ag present at the same time: A polish, with 1 micron-diamond paste on felt with a kerosene lubricant, was followed with 10% oxalic acid and alumina on silk velvet cloth, and finally with ferric oxide plus 20% chromic acid on soft-napped cloth of cashmere wool. Etching was carried out by dipping in a solution of ammonium hydroxide, hydrogen peroxide, and water in the ratio 2:0.3:5. Bright field illumination was satisfactory. An etch with a dilute aqueous solution of nitric acid stained Be-Ag compounds.

3. With Be and Si present at the same time: The same polishing procedure was used as in 1; the samples were etched with 10% HF in ethanol.

The beryllium sheets and rods were manufactured by powder metallurgy techniques and contained about 1 to 2% BeO and 0.3 to 0.4% of other impurities, principally Be_2C, Fe and Al. The beryllium used for alloy preparation contained only 0.5 to 0.6% BeO, as it was obtained as chunks prior to powdering. The purities of the other elements used in this investigation were: silver—99.99%; silicon—97% (remainder —Fe, Al, Ni, Ti); lithium—99.91%; lanthanum—99.4% (remainder cerium).

Results and Discussion

Series of wettability tests were made of silver on beryllium sheets with surfaces prepared by polishing metallographically, etching in 10% HF, grinding through 600 grit, and deeply etching in "beryllium bright dip." Wetting was best on the deeply etched or ground surfaces, similar to results found at room temperature using water containing a few drops of wetting agent. With silver, however, about 2 min elapsed at temperature before the spreading, which was only partial, reached its maximum. Although the beryllium pieces had a light blue or brown haze indicating a very thin oxide film, sections of these wettability tests as in Fig. 4 showed that these films did not appear to inhibit interaction of the two metals. Instead, the partial spreading appeared due to rapid intergranular penetration of liquid silver into beryllium.

Several other points were brought out in these tests:

1. In Fig. 4A it can be seen that recrystallization was just beginning after 2 min at 1832° F. This was then about the limit of the brazing temperatures and times that could be employed; there was thus little hope of success with Be-Si alloys.

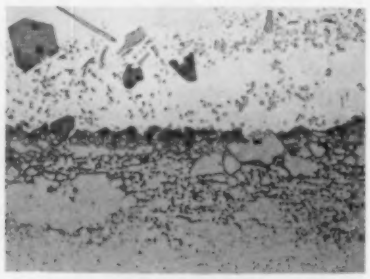
2. Silver did not even partially wet beryllium in a vacuum of 8 to 10 microns.

3. Beryllium grains and a Be-Ag compound actually were lifted from the metal and floated to the top of the pool of silver during the test or during cooling—Fig. 4.

4. Large voids were often found in the silver, even after outgassing the silver in an outgassed crucible. Beryllium contains significant amounts of H_2 and N_2;[11] outgassing studies were not carried out because it was noticed that these voids were never present in brazed joints, perhaps due (*a*) to their dimensions, (*b*) the presence of another piece of beryllium in the direction of gas evolution or (*c*) the pressure applied during brazing.

The intergranular penetration of liquid silver into beryllium is not harmful in contrast to brazing with aluminum and its alloys. It has been shown that a beryllium silver alloy consisting of primary beryllium particles in a continuous silver

(A) As polished—polarized light. × 100



(B) As polished—bright field. × 200

Fig. 4—Cross-section of wettability test with silver on beryllium; plate held at approximately 1832° F for two minutes (silver on top)—reduced 45% on reproduction

Table 2—Tensile Strengths of Beryllium Butt-brazed Joints at Room and Elevated Temperatures

Braze material	Test temperature, °F[a]	Heat treat temperature °F[b]	Ultimate tensile strength, psi	Yield strength at 0.2% offset, psi	Location of failure
Silver sheet (2 mils thick)	R. T.	None	32,800 ± 4640 (5)[c]	30,200 ± 6000 (3)	Base metal or braze-base metal interface
Silver sheet (2 mils thick)	R. T.	700	32,300 ± 2500 (2)	33,100 (1)	Joint
Silver sheet (2 mils thick)	R. T.	1350	32,800 ± 1800 (3)	29,900 ± 200 (2)	Joint or base metal
Silver sheet (2 mils thick)	R. T.	1450	28,600 ± 3500 (3)	...	Joint
Silver sheet (2 mils thick)	700	None	29,300 ± 600 (3)	...	Base metal
Silver sheet (2 mils thick)	700	700	25,900 ± 5300 (3)	...	Joint
Silver sheet (2 mils thick)	1350	None	6630 ± 530 (2)	...	Joint
Silver sheet (2 mils thick)	1350	1350	6430 ± 60 (2)	...	Joint
Silver sheet (2 mils thick)	1450	None	2250 ± 190 (2)	...	Joint
Silver sheet (2 mils thick)	1450	1450	1980 ± 70 (3)	...	Joint
Be-20 % Ag (14 mils thick)	R. T.	None	30,600 ± 5300 (3)	29,500 ± 100 (2)	Braze-base metal interface or base metal
Be-20 % Ag (2 to 5 mils thick)	R. T.	None	32,900 ± 1000 (3)	30,000 ± 400 (3)	Joint or braze-base metal interface
Be-20 % Ag (2 to 5 mils thick)	R. T.	700	31,800 ± 3600 (3)	32,000 (1)	Joint
Be-20 % Ag (2 to 5 mils thick)	R. T.	1350	28,900 ± 3800 (3)	...	Joint
Be-20 % Ag (2 to 5 mils thick)	R. T.	1450	28,100 ± 500 (3)	...	Joint
Be-20 % Ag (2 to 5 mils thick)	700	None	27,900 ± 1900 (3)	...	Base metal or interface
Be-20 % Ag (2 to 5 mils thick)	700	700	30,500 (1)	...	Joint
Be-20 % Ag (2 to 5 mils thick)	1350	None	4200 ± 400 (3)	...	Joint-base metal interface
Be-20 % Ag (2 to 5 mils thick)	1350	1350	6100 ± 300 (3)	...	Joint
Be-20 % Ag (2 to 5 mils thick)	1450	None	2060 ± 40 (3)	...	Joint-base metal interface
Be-20 % Ag (2 to 5 mils thick)	1450	1450	2490 ± 210 (2)	...	Joint-base metal interface
Ag plate (5 microns on each face)	R. T.	None	39,200 ± 2900 (2)	...	Base metal or joint
Ag plate (5 microns on each face)	R. T.	700	35,925 ± 225 (2)	...	Joint
Ag plate (5 microns on each face)	R. T.	1350	13,200 ± 2000 (2)	...	Joint
Ag plate (5 microns on each face).	R. T.	1450	7500 ± 800 (2)	...	Joint
Be-35 % Si sheet (25 mils)	R. T.	None	17,500 ± 1300 (2)	...	Joint or interface

matrix is ductile.[12] This is illustrated in Fig. 5.

Silicon also penetrates beryllium rapidly and intergranularly. With all alloys there was no spreading at all, only intergranular penetration of the silver or silicon from the matrix of the braze into the beryllium. (Thickness of the braze alloy was thus unimportant.) None of the ternary additions seemed to affect spreading; butt joints for tensile testing were, therefore, made only with the binary alloys and pure silver.* Typical butt-brazed joints are shown in Fig. 6. The results of 72 of the 76 tensile tests of brazed joints are summarized in Table 2. In Table 3, tensile strengths of hot-pressed beryllium powder are presented.

The strengths of the plated samples at room temperature fell off markedly on extended exposure at 1350° F or above. A reason for this is suggested from a micrographic investigation of typical brazed joints. As shown in Fig. 6A, the joint formed from plated silver contained a fairly continuous interface of silver. The joints prepared by preplacing silver or the beryllium-silver alloy (Fig. 6B, 6C) did not show this, because of the longer brazing time and higher temperature of the braze which allowed more penetration of the silver as compared to the plated samples. As a result, it could be expected that a continuous layer of the peritectoid compound would form between the beryllium and the silver in the plated samples. (Electroplating silver in the joints and heat treating them at a higher temperature than used in this work will be cheaper than preplacing silver foil.)

The 1350° F heat treatment appears to be below the temperature of stability of this compound. How-

* The time-temperature cycle used for brazing with silver foil and the alloys was 5 to 6 min to reach 1922° F (most of this was above the melting point of silver due to an asymptotic approach to the temperature), 30 sec at temperature, followed by cooling with the power off; with the electroplated samples, the time to the brazing temperature (1832° F) for the sample introduced from the cold zone of the furnace was 4 min. The fixture was held for 60 sec at temperature and then removed to the cold zone. Brazing in each instance was conducted in an argon atmosphere at a pressure of 800 microns.

[a] The tests at 1350° and 1450° F were carried out in a flowing argon stream.

[b] All specimens held 24 hr at temperatures indicated. The 700° F heat treatments were carried out in air, while at 1350° and 1450° F they were conducted in an argon atmosphere of 800 microns pressure.

[c] Deviations are arithmetic averages of differences between mean and actual values. The number of values in mean is indicated in parentheses.

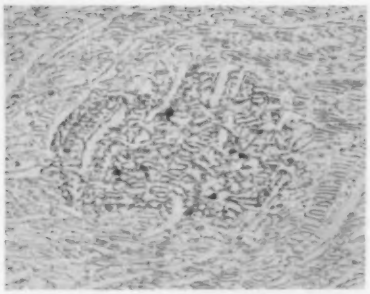


Fig. 5—Specimen from a Be-14.3% Ag ingot rolled at 950° F to a reduction in thickness of 50%; bending of the globular primary phase around an area containing a compound; NH_4OH, H_2O_2 etch. × 100 (Reduced 50% on reproduction)

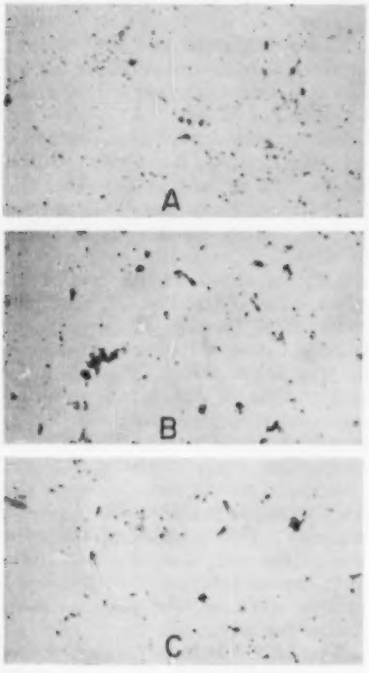


Fig. 6—Typical butt brazed joints brazed with: (A) Electroplated silver (10 microns); (B) silver sheet (2 mils); (C) Be-20% Ag alloy (14 mils); NH_4OH H_2O_2 etch. × 500 (Reduced 45% on reproduction)

ever, the phase diagram is only tentative in the region of the compound. The results reported here indicate that the compound may actually exist at a lower temperature than is indicated in the present diagram (Fig. 1). Joints made with the beryllium-silicon alloys did not have as high strengths at room temperature as the joints with the beryllium-silver alloy or silver and testing at elevated temperatures was not conducted.

Figure 7 shows typical fractures at the joints of brazed samples.

Conclusions

1. Liquid silver and silicon penetrate beryllium rapidly and intergranularly, slowing and limiting spreading; slight tarnishing of the surface does not seem to limit this interaction.

2. With silver, spreading is better in an argon atmosphere than in vacuum.

3. Because of the rapid intergranular penetration of liquid silver in beryllium, the effective joint thickness is quite large with silver or a beryllium-silver alloy as the braze material. This is not harmful, as a two-phase beryllium-silver alloy consisting of primary beryllium particles immersed in a silver matrix is ductile.

4. Butt-joint strengths with silver and a beryllium silver alloy are about 60% that of the base metal at room temperature and 80% at temperatures in the range 700 to 1450° F.

5. Prolonged exposure at temperatures in the range 700 to 1450° F does not affect the room temperature strength of joints brazed with a beryllium–20% (atomic) silver alloy.

6. Prolonged exposure at temperatures at or above 1350° F reduces the strength of joints brazed with silver only if there is a continuous silver interface in the joint. This is probably due to formation of the peritectoid compound in the beryllium-silver system; this work suggests that the compound extends to at least 1350° F, 50° F lower than shown in the tentative phase diagram in the literature.

7. Joints brazed with a beryllium–35% silicon alloy were only one half as strong at room temperature as those brazed with silver or the beryllium-silver alloy (30% of the base metal strength).

Table 3—Tensile Strength of Hot-Pressed QMV Be Powder (—200 mesh)

Test temperature, ° F	Ultimate tensile strength, psi
R. T.	51,000 ±900 (2)[a]
700	33,280 ±500 (2)
1350[b]	8360 ±470 (2)
1450[b]	2725 ±55 (2)

[a] Mean and average of difference between mean and actual values for the number of values indicated in parentheses.
[b] Tests conducted in flowing argon.

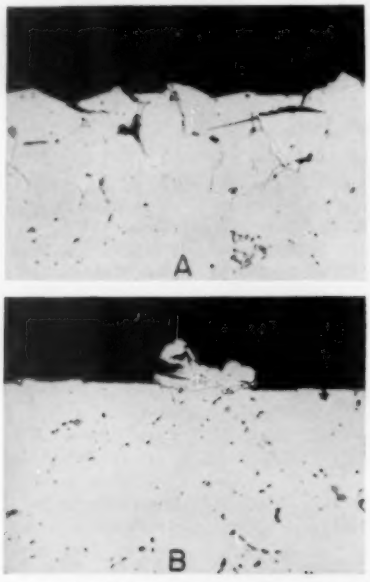


Fig. 7—Typical room-temperature butt-brazed joint fractures: (A) Electroplated silver; (B) Be-20% Ag alloy. As polished. × 500 (Reduced 45% on reproduction)

Acknowledgments

The authors thank the many people who aided this work. Dr. E. Scala and R. Wagner and J. Kent provided helpful discussions. W. Chesley, L. Richards and particularly P. Haritos rendered valuable assistance. J. Boyd developed the metallographic techniques for beryllium and the alloys and is responsible for all the photomicrography. F. Foley developed the procedure for electroplating silver on beryllium. This work was sponsored by the Research and Advanced Development Division, AVCO Corp., and carried out under Contract AF33(616)-5913 with the U. S. Air Force, ARDC.

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Recent Progress in Development of Self-Fluxing, Air Proof Brazing Alloys

Literature review and experimental program demonstrating that Cu alloys with low Li/B ratios appear most suited for brazing in air

BY NIKOLAJS BREDZS AND HARRY SCHWARTZBART

ABSTRACT. A progress report is presented of recent work on the development of filler alloys which may be used to braze steel in air (or less oxidizing, cheaper, exothermic or endothermic industrial gas atmospheres) without flux. The alloys developed contain lithium and boron, which provide the self-fluxing capability. A theoretical discussion of basic mechanisms is presented as well as experimental results. Among the factors considered are the role of moisture when brazing with filler alloys containing no boron, the significance of the lithium/boron ratio, and the viscosity of the flux formed *in situ*.

The most promising alloys developed thus far contain ~78% Cu, 20% Zn, 1½% B and from 0 to ½% Li.

Introduction

This paper presents the results to date of research work on the development of self-fluxing, air proof brazing alloys for joining ferrous and nonferrous alloys in air without fluxes or protective atmospheres. Certain earlier work performed on this subject has been summarized in a series of papers published in the WELDING JOURNAL.[1-3]

Brazing in air without fluxes is of great theoretical interest, because it represents a limiting case that may be encountered in brazing. It also has some practical application, although the point may be raised that an advantage of an external flux is that it prevents oxidation of the base metal away from the joint interface. Possibly the greatest practical significance of the developments described herein is that they may eliminate the need for dry hydrogen furnace atmospheres in the brazing of some alloy and stainless steels, and permit the use of cheaper, safer exothermic or endothermic industrial gas atmospheres. It is apparent that if a self-fluxing brazing alloy can yield strong joints in brazing a given base metal in air, then it will also yield strong joints in brazing the same base metal in less oxidizing atmospheres such as endothermic or exothermic industrial gases. Thus, brazing in air without any fluxes is the extreme case of self-fluxing brazing as far as oxidizing conditions are concerned. Thus it presents the most severe test for the self-fluxing ability of a given brazing alloy.

Theoretical Considerations

It has been shown in the course of the previous work[2,3] that lithium is a most effective component for providing self-fluxing properties to brazing alloys for the following reasons:

1. Only four metals in the periodic system of elements have a higher affinity for oxygen at practical brazing temperatures than has lithium (Table 1). Therefore, lithium, as one of the strongest deoxidizing elements, is especially suitable as a reducing agent for self-fluxing brazing alloys.

2. Lithium is soluble in molten silver, palladium, copper, aluminum, zinc and cadmium, and also, to a large extent, in solid silver and palladium at room temperature.

3. Small additions of lithium considerably lower the wetting contact angle of molten silver, molten copper and some of the silver-base brazing alloys on plain-carbon steels, as well as on alloy steel surfaces, thus promoting good wettability and fluidity of the lithium-bearing, silver-base and copper-base brazing alloys.

The four metals which at practical brazing temperatures have a higher affinity for oxygen than has lithium are: Ca, Be, Mg and Ba (Table 1, second column). However, the melting points of the oxides of these metals are considerably higher than the liquidus temperatures of the highest melting brazing alloys, and even higher than the melting temperatures of the most common base metals, copper and steel (Table 2). Consequently, if one of these four metals is added to a brazing alloy, then, as a result of the reducing reaction taking place at the molten filler metal-solid base metal interface, the base metal oxides will be replaced by the highly refractory oxides of the reducing elements. Of all the five metals which have the highest affinity for oxygen, lithium produces an oxide, Li_2O, with the lowest melting point, 1430° C (Table 2). However, even this melting point is about 500° C higher than the average brazing temperature of most of the commercial brazing alloys.

It has been observed that lithium-bearing brazing alloys show better self-fluxing properties in a less dry protective atmosphere than in a very dry atmosphere. Considering the extremely high affinity of Li_2O for H_2O, it has been postulated that in heating lithium-bearing brazing alloys in an inert atmosphere containing moisture, LiOH will form on the surface of the brazing alloy, in an amount depending on the moisture content of the atmosphere. It is apparent from Table 2 that lithium has a stable hydroxide which does not decompose and is

NIKOLAJS BREDZS and HARRY SCHWARTZBART are associated with Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill.

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Table 1—Free Energy of Formation of Oxides in Kcal per Oxygen Gram-atom[11]

At 227° C		At 727° C		At 1227° C		At 1727° C	
Ag	+0.06	Cu	−23.3	Cd	−14.4	Na	−7.9
Hg	−8.8	Pb	−28.7	Cu	−15.2	Cu	−10.7
Cu	−31.5	Ni	−35.0	Pb	−18.7	Ni	−13.0
C (O)	−37.1	Co	−38.8	Ni	−24.2	Zn	−15.0
Pb	−40.4	Cd	−37.7	Co	−29.5	Co	−19.9
Ni	−46.1	Fe	−47.8	Na	−38.6	Fe	−33.8
Co	−47.9	C	−47.9	Zn	−38.9	Cr	−49.1
Cd	−50.4	Zn	−61.4	Fe	−40.0	Mn	−55.1
Fe	−55.5	Na	−65.5	C	−58.3	U	−59.6
Zn	−71.3	Cr	−69.7	Cr	−59.5	V	−60.5
Cr	−81.6	Mn	−74.5	Mn	−65.6	Si	−61.9
Na	−83.0	V	−79.0	V	−69.5	B	−65.0
Mn	−83.1	B	−81.7	B	−73.1	C	−58.5
V	−89.0	Si	−83.4	Si	−73.1	Ti	−70.1
B	−91.2	Ti	−91.1	Ti	−80.5	Mg	−76.1
Si[a]	−94.0	Al	−108.2	Li	−92.0	Al	−82.0
Ti[b]	−101.2	U	−109.0	Al	−95.1	Ba	−86.0
U	−119.1	Li	−110.2	U	−98.8	Ca	−95.5
Al	−120.7	Ba	−110.5	Ba	−99.0	Be	−96.6
Ba	−121.5	Mg	−117.7	Mg	−101.3		
Li	−127.7	Be	−119.6	Be	−108.3		
Mg	−130.8	Ca	−126.0	Ca	−113.3		
Be	−131.3						
Ca	−138.2						

[a] Quartz.
[b] Rutile.

liquid in the 450–924° C temperature range.* Moreover, molten lithium hydroxide can dissolve almost every known metal oxide, with very few exceptions. Accordingly, at temperatures above 450° C in an inert atmosphere containing some small amounts of moisture, a brazing alloy containing sufficient amounts of lithium should form a thin film of flux consisting mostly of LiOH. This molten flux layer should protect the lithium in the filler metal from further oxidation, thus leaving enough lithium for reducing the base metal oxides on the surface of the solid base metal, provided that the filler alloy melts below 924° C.

From these theoretical considerations it is apparent that lithium-bearing brazing alloys cannot have self-fluxing abilities in an absolutely dry inert atmosphere or in dry air. In an absolutely dry atmosphere there is no water vapor available to form a low-melting LiOH film on the surface of the filler metal and at the solid base metal-solid filler metal interface, as there is in the case of wet atmospheres. Therefore, in an absolutely dry atmosphere the result of the reduction of the base metal oxides at the solid base metal-liquid filler metal interface will be of a layer of Li_2O. The melting point of Li_2O, 1430° C, however, is much higher than the melting temperatures of most of the base metals, and therefore no metallic bond will be obtained. In order to utilize the self-fluxing abilities of lithium-bearing brazing alloys in absolutely dry atmospheres, it was necessary to lower the melting point of lithium oxide. It was postulated that this problem could be solved by adding another highly reducing element to a lithium-bearing alloy. This element should have about the same high affinity for oxygen at brazing temperatures as lithium. In heating such an alloy in absolutely dry air, two oxides should form simultaneously on the surface of the alloy: lithium oxide and the oxide of the other highly reducing element. The most important requirement for obtaining self-fluxing properties in dry air is that the binary phase diagram of the two oxides has at least one eutectic point with a melting temperature considerably below the solidus temperature of the given filler metal. If this requirement is fulfilled, then, by heating such an alloy in air, the low-melting, liquid mixture of the two oxides will constitute a flux which will protect the brazing alloy from any further oxidation during the melting process. Furthermore, this low-melting, liquid mixture of the oxides might even dissolve the oxides on the surface of the base metal, provided that the quantities of lithium and the other highly reducing element are sufficiently high to form enough of the low-melting eutectic flux.

According to these requirements, it was found that the combination of lithium and boron, for the following reasons, is almost ideal for composing self-fluxing alloys for brazing in absolutely dry air:

1. Both lithium and boron have high affinity for oxygen at brazing temperatures (Table 1). Accordingly, during the heating and the subsequent melting process, both Li_2O and B_2O_3 should form on the surface of the brazing alloy.

2. According to the binary phase diagram Li_2O–B_2O_3, lithium oxide and boron oxide form a series of low-melting compounds and mixtures of compounds (Figs. 1 and 2). The melting temperatures of these mixtures over a large range of compositions are considerably lower than the solidus temperatures of most of the silver-base and copper-base brazing alloys.

3. Lithium borates have excellent fluxing properties provided that the high viscosity of these borates can be sufficiently lowered. The ability of the borates of alkali metals to dissolve refractory oxides readily is well known from analytical chemistry.

In heating a silver-base or copper-base self-fluxing brazing alloy containing Li and B in wet air, two compounds will form simultaneously on the surface of the alloy: LiOH and B_2O_3. Consequently, there will be formed on the surface of the brazing alloy lithium borates of various compositions, or, more correctly, mixtures of lithium borates of various compositions. The exact composition of these mix-

* Considering the melting points and decomposition temperatures of the hydroxides, it is apparent that Ba is another potential candidate for composing self-fluxing alloys.

Table 2—Melting Points of Oxides and Hydroxides

	Oxide		Hydroxide		
Metal	Formula	Melting point, °C	Formula	Melting point, °C	Decomp. temp., °C
Ba	BaO	1925	$Ba(OH)_2 \cdot 8H_2O$	78	$-9H_2O$, 720
Li	Li_2O	1430	LiOH	450	$-H_2O$, 924
Mg	MgO	2770	$Mg(OH)_2$	...	$-H_2O$, 350
Be	BeO	2530	...	...	...
Ca	CaO	2580	$Ca(OH)_2$	...	$-H_2O$, 580

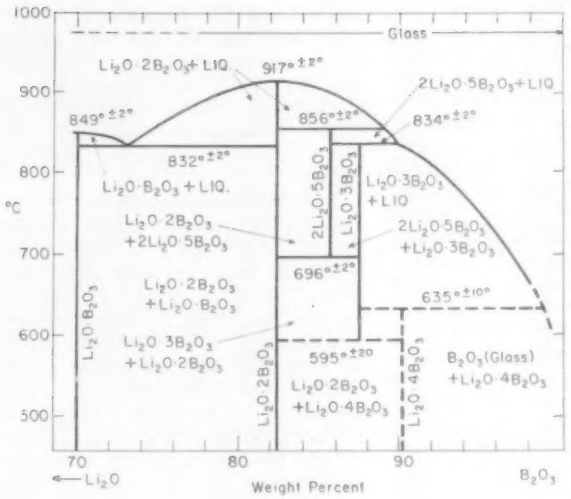

Fig. 1—System Li_2O-B_2O_3-B_2O_3 according to B. S. R. Sastry and F. A. Hummel[4]

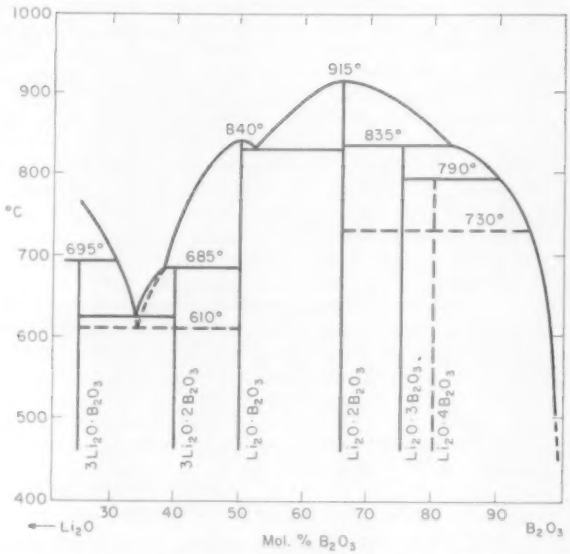

Fig. 2—System Li_2O–B_2O_3 according to Antonine P. Rollet and Roger Bouaziz[5]

tures will depend on the Li/B ratio in the brazing alloy. Depending on this ratio, the following chemical reactions might take place on the surface of the brazing alloy:

1. At the lowest Li/B ratio: $2LiOH + 5B_2O_3 = Li_2B_{10}O_{16} + H_2O$ ($Li_2B_{10}O_{16}$-lithium pentaborate).
2. At higher Li/B ratio: $2LiOH + 2B_2O_3 = Li_2B_4O_7 + H_2O$ ($Li_2B_4O_7$-lithium tetraborate).
3. At the highest Li/B ratio: $2LiOH + B_2O_3 = 2LiBO_2 + H_2O$ ($LiBO_2$-lithium metaborate).

The melting temperatures of the various lithium borates and their mixtures have been recently determined by Sastry and Hummel,[4] and Rollet and Bouaziz,[5] who investigated the B_2O_3-rich section of the Li_2O-B_2O_3 phase diagram (Figs. 1 and 2).

It is well known from inorganic chemistry that all the lithium borates and their mixtures are quite hygroscopic. In Table 3 are summarized all available data on the composition of various isolated lithium borates, their melting temperatures, the composition of their hydrates, and the decomposition temperatures of the various hydrates. From these data it is apparent that at temperatures above 350° C all the lithium borates and their mixtures, with the exception of the mixtures with very high Li/B ratio, are completely anhydrous, i.e., without any traces of water of crystallization. In the composition range of high Li/B ratio the decomposition temperature of the hydrates increases from 160° C for lithium metaborate to 924° C for pure lithium hydroxide.

This means that as the result of heating self-fluxing brazing alloys containing Li and B at temperatures above 350° C, a flux layer consisting of anhydrous lithium borates will form on the surface of the brazing alloy in wet as well as in dry air, provided that the Li/B ratio is not too high. It is significant that the lithium borates are anhydrous, since they are, therefore, more efficient in their ability to dissolve metallic oxides than if they contain water of crystallization. From these theoretical considerations it is apparent that self-fluxing brazing alloys containing B and Li, with a low Li/B ratio, are best suited for air-brazing purposes, and also for brazing in less oxidizing industrial gas atmospheres.

We have so far discussed the relationship of composition to the ability to reduce and dissolve metallic oxides, the relationships among the melting range of the filler alloy, the melting point of the flux formed *in situ* in the joint, the decomposition temperature of the hydrate, and the moisture content of the atmosphere. One more important factor bears considera-

Table 3—Melting Temperatures of Boron Oxide, Lithium Oxide, and Various Lithium Borates, and the Decomposition Temperatures of Their Hydrates

Li/B ratio, atomic, %	Formula	Melt. temp. of the anhydrous compound, °C.	Comp. of the hydrate	Decomp. temp. of the hydrate, °C
~	Li_2O	1430	$LiOH \cdot H_2O$	$-H_2O$, 100–110°
			$LiOH$	$2LiOH \rightarrow Li_2O + H_2O$, at 924°
1	$Li_2O \cdot B_2O_3$ (lithium metaborate)	849	$LiBO_2 \cdot 8H_2O$	$-6H_2O$, 36.9° $-8H_2O$, 160°
0.5	$Li_2O \cdot 2B_2O_3$ (lithium tetraborate)	917	$Li_2B_4O_7 \cdot 5H_2O$	$-2H_2O$, 200° $-5H_2O$, 235°
0.33	$Li_2O \cdot 3B_2O_3$	834	$LiB_3O_5 \cdot 3H_2O$	
0.25	$Li_2O \cdot 4B_2O_3$	635	$Li_2B_8O_{13} \cdot 10H_2O$	
0.20	$Li_2O \cdot 5B_2O_3$ (lithium pentaborate)	~600	$Li_2B_{10}O_{16} \cdot 8H_2O$	$-H_2O$, 110–120° $-H_2O$, 120–150° $-6H_2O$, 150–200° $-8H_2O$, 300–350°
0	B_2O_3	450	H_3BO_3	$2H_3BO \rightarrow B_2O_3 + 3H_2O$ at 300°

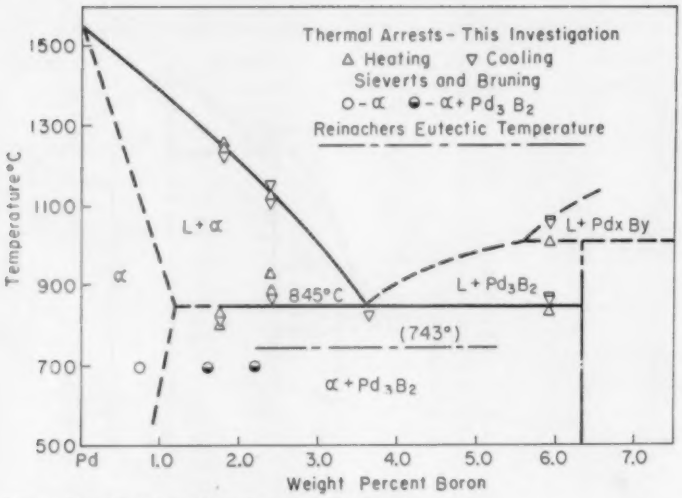

Fig. 3—The Pd-rich section of the Pd-B system[8]

tion, that of viscosity of the flux formed *in situ* during and after all of the chemical reactions have occurred. Viscosity is significant in determining the propensity for slag entrapment in the joint. In this connection, it is relevant, as will be seen from the experimental results presented in the next section, that the $Li_2O \cdot B_2O_3$-B_2O_3 phase diagram determined by Sastry and Hummel[4] (Fig. 1) shows that the liquids at the high B_2O_3 end of the diagram are glassy, therefore, highly viscous. The implication is that the liquids are not so glassy and viscous as the Li content increases.

Viscosity can be altered by further additions to the filler alloy, and this approach was utilized in the current alloy development program, as will be seen in the next section.

Experimental Program

Cu-Ni-Li-B Alloys (U. S. Pat. 2,768,893)

The first experimental self-fluxing, air proof brazing alloys containing lithium and boron were prepared by dissolving small amounts of boron in molten nickel until the eutectic composition, 96% Ni – 4% B, with a melting point of 1140° C (2048° F) was obtained. This eutectic was completely dissolved in molten copper to make an 80% Cu 19.2% Ni – 0.8% B alloy.

By adding to the 80% Cu – 19.2% Ni – 0.8% B alloy about 5 wt-% of lithium, an alloy of the following nominal composition was obtained: 76.2% Cu, 18.3% Ni, 4.75% Li, 0.75% B. The melting range of this alloy was approximately 1900–2000° F. With this alloy, plain-carbon steels, alloy steels and stainless steels have been brazed in air without fluxes or protective atmospheres. The maximum tensile strength of butt joints in SAE 1020 steel was 50,000 psi.†

These alloys, however, do not have commercial application for two reasons: (1) The tendency to segregate, especially when made in commercial quantities, even when prepared using fast cooling such as chill casting, and (2) the high corrosion rate of such alloys in water. Both of these phenomena arise because of the complete insolubility of lithium in either molten or solid nickel and in solid copper. Considering these undesirable properties, it was attempted to find a metal which could dissolve larger quantities of lithium and boron without segregating.

Ag-Li-B Alloys

Silver retains up to 5 wt-% of lithium in solid solution at room temperature.[6] Accordingly, silver would be an excellent base for composing self-fluxing filler alloys containing lithium and boron, provided boron is soluble in silver. Investigations of the silver-boron phase diagram show insolubility of boron in molten silver,[7] although the work referenced is quite old.

It was attempted in this program to prepare silver-boron alloys by melting pure silver with commercial ferro-boron containing 11% B in alundum crucibles under 10% H_2 – 90% N_2 atmosphere. In order to separate the low-melting, silver-rich phase from the high-melting iron-rich phase, the crushed Ag-Fe-B ingots were remelted in an alundum crucible with a 1/8-in. hole drilled in the bottom. The low-melting phase flowed through this hole into another alundum crucible directly below.

The chemical analysis of the low-melting, silver-rich phase yielded 99.24% Ag, 0.73% B, 0.03% Fe. Attempts to make this alloy self-fluxing and air proof by adding various amounts of lithium were unsuccessful. The resulting Ag-B-Li alloys did not wet either plain-carbon or alloy steel surfaces. Presumably, due to the low affinity of silver for boron and the high affinity of iron for boron, all the boron was tied up at the steel-molten filler metal interface before the filler metal could penetrate into the capillary gap of the steel joints.

Ag-Pd-Li-B Alloys

A literature search has revealed that no work has been done on the Pd-Li binary phase diagram, and only scanty data were available concerning the Pd-B system.

As part of this program, it was demonstrated that molten palladium dissolves about 5% by weight of lithium, that the resulting 95% Pd – 5% Li alloy has a considerably lower melting temperature than has pure Pd, and that a large part of the dissolved lithium in the 95% Pd – 5% Li alloy is retained in solid solution at room temperature, in fashion similar to the Ag-Li system. Accordingly, it was postulated that there should be no difficulties in developing Pd-Li-B alloys, provided that boron is soluble in molten palladium.

Because of the lack of data in the literature, some work was performed on the Pd-rich end of the Pd-B phase diagram.[8] The results are presented in Fig. 3. It is seen that the eutectic composition lies at 96.5% Pd – 3.5% B, and melts at 845° C. The solid solubility of boron in palladium is 1.2 wt-% at 845° C.

Alloys of palladium containing 2 and 3% boron were utilized to braze low and high-carbon steel in 90% N_2 – 10% H_2 atmosphere. Upon examination of the brazed bars, it was found that the Pd-B alloys dissolved large quantities of steel base metal, so that as a result of the brazing operation the joints were much thicker than the capillary before brazing. The joints brazed with the 97% Pd – 3% B alloy had the higher strength. The average tensile strength of these joints was in the range of 50,000 to 63,000 psi, which is surprisingly high, especially

† In regard to experimental procedures throughout this program, butt joints were brazed in 3/4-in. diam bars, using induction heating. In every case, the brazing temperature was just in excess of the liquidus of the filler alloy. After brazing, the specimens were turned down to about 1/2 in. diam and tension tested.

considering that the tensile strength of pure, annealed palladium is only 21,000 psi.

These results indicated the promise of Pd-B base brazing alloys and possibly Pd-B-Li base self-fluxing air proof brazing alloys. It was felt necessary, however, to reduce the solubility of these filler alloys for iron, so as to minimize base metal dissolution during brazing, and because the iron dissolved in the filler alloy would cause the rejection of a lithium-rich phase.

It was postulated that the solubility of iron could be reduced considerably by adding silver or copper to the Pd-B alloys. Accordingly, Ag-Pd-B alloy was prepared by replacing half the palladium with silver in a 97% Pd – 3% B alloy. The resulting 50.0% Ag – 48.5% Pd – 1.5% B alloy was not single phase. Metallographic examination of the polished cross section of this alloy revealed a very fine net of white silver surrounding the grains of the otherwise homogeneous Ag-Pd-B alloy, indicating that 50% silver is apparently the highest amount which the 97% Pd – 3% B alloy can dissolve without separation of silver.

Attempts to make such alloys self-fluxing and air proof by adding lithium were unsuccessful in that there was evidence of considerable separation of the alloying elements, as noticed in the fracture surfaces. Apparently, the Pd-Ag-Li-B alloys in the brazed joints dissolved large quantities of iron which rejected the lithium from the filler metal, causing the separation of the filler metal into two phases: a Pd-Fe rich phase and an Ag-Li rich phase. As the result of this segregation, the mechanical strength of the joints was quite low. Much better results were obtained with Pd-Ni-Li-B and Pd-Cu-Ni-Li-B alloys, which are described in the following section.

Pd-Ni-Li-B Alloys (U. S. Pat. No. 2,903,-352); Pd-Ni-Cu-Li-B Alloys (U. S. Pat. No. 2,903,353)

The Pd-Ni-Li-B alloys, in respect to composition, properties and air-brazing abilities, are quite similar to the Cu-Ni-B-Li alloys. The only difference between these two groups of alloys is the substitution of palladium for copper, which was felt might improve the strength and the oxidation resistance of the joints at high temperatures.

The best air-brazing properties were obtained with an alloy, melting at about 2000° F, of the following nominal composition: 66.5% Pd, 28.8% Ni, 3.5% Li, 1.2% B. It yielded excellent wettability on surfaces of plain-carbon steels, as well as on alloy steels. It was capable of brazing 303 stainless steel without any fluxes or protective atmospheres. Joints in 303 stainless steel brazed in air yield an average tensile strength of about 40,000 psi. It has been shown that 95.0% Pd – 5.0% Li alloy can be easily alloyed with the Cu-Ni-B alloys. The Pd-Ni-Cu-Li-B alloys obtained also yielded quite good air-brazing properties.

Cu-Zn-B-Li Alloys and Cu-Zn-B Alloys

Although the theory underlying the development of air proof self-fluxing alloys containing boron and lithium was confirmed by experimentation, it was not initially understood why boron alone, without lithium, should not make an alloy self-fluxing or air proof. Boron at 727° C—that is, in the practical brazing temperature range—has only a slightly lower affinity for oxygen (−81.7 k-cal/gram atom) than has lithium (−110.2 k-cal/gram atom). The product of the oxidation reaction of the boron-bearing brazing alloy, B_2O_3, has the lowest melting point (450° C) of all the compounds and mixtures of compounds in the entire Li_2O-B_2O_3 phase diagram. Consequently, pure Cu-B alloys, without any additions of lithium, should have the most effective self-fluxing properties. However, experimental results did not confirm this postulation.

Further experimentation finally resolved this dilemma. A series of wettability experiments performed with pure, calcinated B_2O_3 and $Li_2O \cdot 4B_2O_3$ showed that these compounds do not spread over oxidized steel surfaces, not even at the melting point of pure copper. The high viscosity of these fluxes retarded spreading on steel surfaces.

B. S. R. Sastry,[9] who investigated the Li_2O-B_2O_3 phase diagram, found that most of the Li_2O-B_2O_3 compounds, and mixtures of compounds, are glass-like, viscous substances in the molten state. It is also well known that the manufacturers of brazing fluxes add alkali fluorides and alkali borofluorides to the borates of alkali metals, H_3BO_3 and B_2O_3, in order to decrease the viscosity of these compounds. Since it is not feasible to include the element fluorine as a constituent into self-fluxing brazing alloys, it was attempted to lower the viscosity of the glass-like Li_2O and B_2O_3 mixtures by adding about 40% ZnO to the lithium tetraborate. The viscosity of the molten 60% $Li_2O \cdot 4B_2O_3$ – 40% ZnO mixture is much lower than the viscosity of the lithium tetraborate. Also, the spreading on hot steel surfaces increased considerably.

Further work was devoted to a determination of the optimum composition of Cu-Zn-B-Li alloys for obtaining low-viscosity fluxes in brazing in air. First, it was necessary to determine the optimum boron content. For this purpose, a series of Cu-B alloys was prepared by melting pure copper with the commercial 97.0% Cu – 3.0% B alloy in various proportions.

The wettability tests performed in air on polished surfaces of low-carbon steel showed that, relatively, best wettability is obtained with 98.5% Cu – 1.5% B alloy. Accordingly, all the Cu-Zn-B-Li alloys were prepared with a boron content of 1.5% B.

The tensile properties of brazements made in air with Cu-Zn-B and Cu-Zn-B-Li alloys are presented in Table 4. For the first three alloys, strength ranged from 30,800 to 68,000 psi, there being no clear effect of lithium content. The alloy containing 1.07% lithium did not wet the steel surfaces, and no bond was obtained. These results show very effectively that adequate additions of zinc to the Li-B type air-brazing alloys can considerably improve the self-fluxing properties of these alloys. This can be explained by the ability of the zinc oxide to reduce considerably the viscosity of the glass-like Li_2O-B_2O_3 fluxes.

The various experiments performed with the Cu-B alloys resulted in the development of a simple and inexpensive method of producing copper-boron alloys with various boron contents by extracting boron into the molten copper from a layer of molten iron-boron alloy, or a low-grade commercial ferro-boron (U. S. Pat. 2,854,332).

Discussion

In reviewing the experimental data obtained until now in developing self-fluxing, air proof brazing alloys, it is apparent that all the alloys which have shown some air-brazing abilities can be divided into two characteristic groups:

1. Air-brazing alloys with a low Li/B ratio.
2. Air-brazing alloys with a high Li/B ratio.

In Table 5 are presented the compositions and the corresponding Li/B ratios of these alloys. According to these data, in the first group, which comprises the Cu-Zn-B-Li alloys, the Li/B ratio covers the range from 0 to 0.53.

Table 4—Tensile Test Results of Low-carbon Steel Bars Brazed in Air with Cu-Zn-B and Cu-Zn-B-Li Alloys

Specimen no.	Average joint thickness, in.	Ultimate tensile strength, psi	Appearance of bond
1. 78.5% Cu – 20.0% Zn – 1.5% B mp 1000° C			
0	0.0050	30,800	Small voids (10%)
00	0.0057	42,100	Voids and interface failure (10%)
000	0.0059	46,300	Almost voidless (5%)
2. 78.38% Cu – 19.97% Zn – 1.5% B – 0.15% Li			
1-0	0.0040	44,500	Small voids (5%)
1-00	0.0032	41,200	Small voids (10%)
1-000	0.0044	45,000	Interface failure (40%)
3. 78.10% Cu – 19.90% Zn – 1.5% B – 0.5% Li			
2-0	0.0025	68,000	Slight interface failure (5%)
2-00	0.0063	36,400	Small voids (5%)
2-000	0.0054	42,100	Small voids (5%)
4. 77.65% Cu – 19.79% Zn – 1.49% B – 1.07% Li			
No wetting of the steel surfaces, no strength			

Table 5—Composition and the Li/B Ratio of Various Air-brazing Alloys

Composition	Li/B ratio, atomic, %
Group I	
1. 78.5% Cu – 20.0% Zn – 1.5% B	0
2. 78.38% Cu – 19.97% Zn – 1.5% B – 0.15% Li	0.16
3. 78.10% Cu – 19.90% Zn – 1.5% B – 0.5% Li	0.53
Group II	
4. 66.5% Pd – 28.8% Ni – 3.5% Li – 1.2% B	4.7
5. 76.2% Cu – 18.3% Ni – 4.75% Li – 0.75% B	10.0

By increasing the Li/B ratio above 0.53, the air-brazing ability drops rapidly. For instance, the 76.65% Cu – 19.79% Zn – 1.49% B – 1.07% Li alloy (alloy No. 4, Table 4), which has a Li/B ratio close to 1.1, did not even wet the steel in air. However, the air brazing ability is regained again when the Li/B ratio is raised to 4.7 and 10.

In postulating the requirements for an effective self-fluxing, air-proof brazing alloy, it was recognized that the best air-brazing abilities should be exhibited by alloys with such Li/B ratios, which upon heating in air will produce fluxes with the lowest possible melting temperature. From the Li_2O-B_2O_3 binary phase diagram, presented in Fig. 2, it is evident that the lowest melting points in the Li_2O-B_2O_3 system are exhibited by the two compositions which have the following Li_2O-B_2O_3 ratios:

1. Li_2O-B_2O_3 = 2:1, mp – 610° C
2. Li_2O-B_2O_3 = 0:1, mp – 450° C

Thus, the two low-melting regions in the Li_2O-B_2O_3 phase diagram might be used as a first approximation for a reasonable explanation of why the best air-brazing abilities are exhibited by the two groups of alloys containing Li and B: the one with a low Li/B ratio, and the other group with a high Li/B ratio. However, melting point as a function of Li/B ratio is but one factor which determines the air-brazing abilities of the alloys containing Li and B. Another, not less important factor is the viscosity of the various Li_2O-B_2O_3 mixtures in the liquid state.

It has been stated already, in discussing the properties of the steel joints brazed with the Cu-Ni-B-Li alloys, that the air-brazing alloys with a high Li/B ratio have no practical significance because of (1) the tendency to segregate, and (2) high-corrosion rates in water

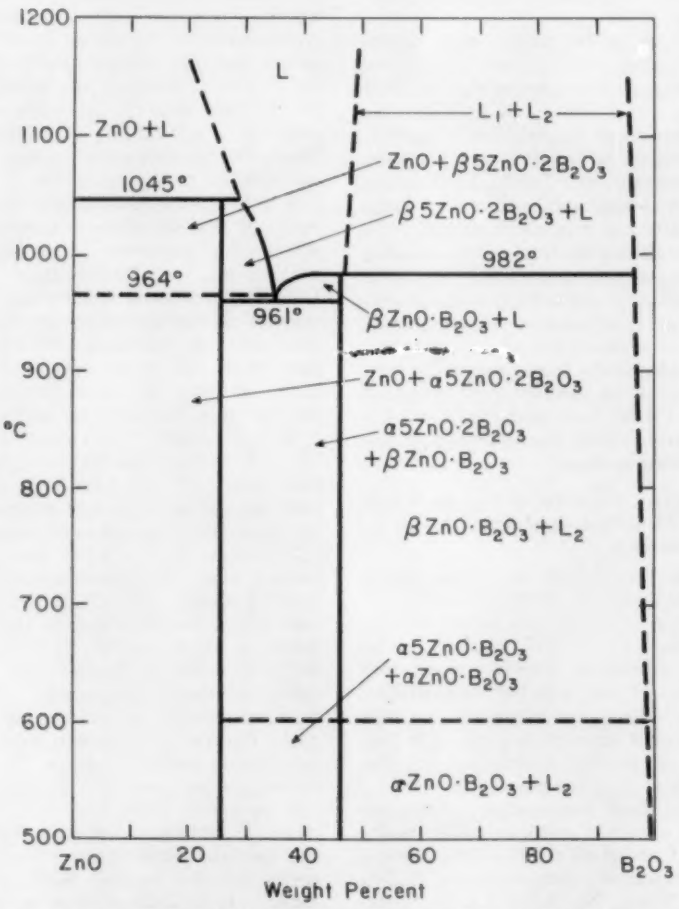

Fig. 4—System ZnO–B_2O_3 according to D. E. Harrison and F. A. Hummel[10]

and in air. These are also likely characteristics of the Pd-Ni-Li-B alloy of Table 5, because the presence of the nickel would cause rejection of a lithium-rich phase. Therefore, of the alloys studied, the only ones that might have practical applications are those in Group I, having a low Li/B ratio. It was stated before that, in heating the Cu-B-Li alloys in air, the resulting Li_2O-B_2O_3 fluxes, especially the ones with the lowest Li_2O-B_2O_3 ratio, are extremely viscous, glass-like substances. Since ZnO lowers considerably the viscosity of the molten Li_2O-B_2O_3 mixtures, it was attempted to add zinc to the Cu-B-Li alloys in order to provide them with air-brazing abilities, i.e., greater fluidity. The experimental results presented in Table 4 show that these attempts were quite successful. Nevertheless, it is rather obvious that in order to obtain optimum compositions for the best air-brazing abilities of the Cu-Zn-B-Li alloys, it is necessary to investigate the B_2O_3-rich corner of the B_2O_3-Li_2O-ZnO ternary phase diagram. Unfortunately, no work has been done on the investigation of this system.

Harrison and Hummel,[10] who have performed the most recent investigation of the B_2O_3-ZnO binary phase diagram (Fig. 4), have found that most of the various B_2O_3-ZnO mixtures in the liquid state are glasses with high viscosity. Therefore, the investigation of the viscosity of the liquid glass-like mixtures in the B_2O_3-Li_2O-ZnO system appears to be the most important prerequisite for attaining further progress in the development of self-fluxing, air-proof brazing alloys.

Conclusions

Cu-Zn-B-Li alloys with low Li/B ratios, or even completely without lithium, appear to be best suited for brazing in air without any fluxes or protective atmospheres. Alloys of this system shown to be self-fluxing and air proof in this study were of the following composition: 78% Cu, 20% Zn, 1 1/2% B, and from 0 to 1/2% Li.

Acknowledgment

The authors wish to express their appreciation to the Lithium Corp. of America for sponsoring this investigation.

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EUROPEAN WELDING RESEARCH

(*Continued from page 105-s*)

carbide had been dissolved during welding. The minimum temperature for stress relief without danger of intergranular corrosion was 1290° F.

This issue also lists the results of hot tensile tests on brazed and silver soldered lap joints in Types 302 and 321 stainless steels 0.020 and 0.039-in. thick. Even heating to 212° F lowered the strength of the Type 302 joints to 75% of their strength at room temperature. The specimens had almost no strength at 930° F. The joints in Type 321 were about 40% stronger at 570° F than the joints in Type 302 due to the tendency of titanium to alloy with the brazing and silver soldering materials.

The last article is a description of a remote controlled fine-wire CO_2 welding robot for welding in the vicinity of radioactivity as on plates or pipes at high preheat.

WEST GERMANY

The July 1960 issue of *Schweissen und Schneiden* contains the following research:

A paper presented before the German Metallurgical Society in 1957 is reprinted in this issue. The paper deals with the high ratio of yield-to-tensile strength commonly found in mild steel weld metal. It is shown that the high ratio applies to covered electrodes, CO_2 and argon welds and also to Monel Metal and titanium welds. Some evidence is presented to show that the yield rises as the Si:Mn ratio is increased from 0.5 to 1.0. Since manganese enlarges the lattice while silicon contracts it, a coupling effect is postulated that raises the yield strength. The coupling involves the simultaneous expansion of the lattice by manganese and contraction by silicon at areas of microsegregation and dislocation.

A translation of a Spanish paper points out the advantage of the wedge test for estimating the hardness under a weld bead as the thickness of the steel is varied. A bead is deposited on a wedge cut from the steel under investigation. For steels containing 0.23 to 0.80% C, the critical cooling rate for martensite is attained within the limits of the wedge.

Continuous cooling transformation curves are given for five steels: (*a*) 0.22 C, 1.0 Cr, 0.2 Mo; (*b*) 0.13 C; (*c*) 0.19 C, 1.2 Mn; (*d*) 0.18 C, 0.8 Cr, 0.4 Mo; (*e*) 0.44 C. A nomogram is given for determining energy input from travel speed, amperage and voltage. Also cooling curves are plotted for root beads and surface beads for several heat inputs, with and without 300° F preheat.

A translation from a Russian magazine presents the good results of depositing steel electrodes in an atmosphere of steam.

Use of the Center Notch-Tensile Test to Evaluate Rocket-Chamber Materials

ASME-sponsored paper demonstrates versatility of center notch-tensile test for evaluating rocket-chamber materials and for selecting fabrication procedures as well as developing new alloys

BY JOSEPH J. WARGA

Introduction

The use of a material for a specific application requires a knowledge of the mechanical properties contributing to the suitability of the material for the application. Thus, to use a material in a static structure, one must know its yield strength in tension or compression, its ultimate strength, its yield strength in bearing and its shear strength. For dynamic structures, further requirements are added—namely, knowledge of the fatigue endurance limit and knowledge of the resistance to impact loads. For both static and dynamic structures, knowledge of the ductile-to-brittle transition temperature may assume importance.

What test or tests, then, can be used to judge the suitability of a material for solid rocket chambers? What properties are required of a material that is subjected to a gaseous pressure load that reaches a maximum in milliseconds? Such a material must resist the effects of stress concentrations produced by discontinuities and contour variations caused by welding. Moreover, the material must be as thin as possible in order to decrease the ratio of inert weight to propellant weight.

The problem has been recognized. Sachs[1] in a study of high-strength steels for oleo cylinders of landing-gear struts, proposed that evaluation be based on results obtained in the notch-tensile testing of bar specimens. Brown[2] has extended Sach's work and has been using a notch-tensile specimen suitable for sheet stock. Instrumented bulge tests, to simulate the membrane stresses of a spherical chamber, have been proposed and used by Fisher.[3] An instrumented bend test to evaluate the effect of heat-treatment on ductility has been developed by Hanink.[4] Center notch-tensile tests suitable for plate and sheet stock have been proposed and are being used by Irwin[5,6] and Srawley[7,8] of the U. S. Naval Research Laboratories. Puzak[9] has suggested an impact-bulge test originally developed for evaluating the effects of welding. In all the foregoing tests, except the instrumented bulge test, the distinctive feature is measurement of the sensitivity of the material to the presence of notches, either gross or microscopic.

This paper describes results that have been obtained by the use of the center notch-tensile test proposed by Irwin to evaluate rocket chamber materials. As developed elsewhere in the paper, the test has been used by the Aerojet-General Corp. for three distinct purposes:

1. Basic materials evaluation.
2. Evaluation of processing variables.
3. Alloy development.

Description of Test

The basic mechanics of crack propagation were described by Griffith over 30 years ago, resulting in the following relationship:

$$P = \left[\frac{2E\gamma}{\pi(1 - \nu 2)c}\right]^{1/2}$$

describes the minimum tensile stress P, required to propagate a surface crack of atomic width and finite length C, or an interior crack of length $2C$, through a thick plate of elastically isotropic material with Young's Modulus E, surface tension γ and Poisson's ratio ν.

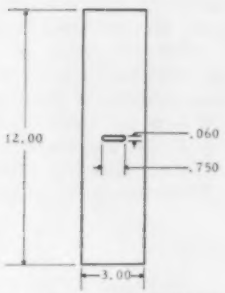

Fig. 1—Irwin-Kies-Smith center notch-tensile specimen*

The inability of this relationship to explain certain observed brittle-fracture characteristics has led many investigators to examine the fracture mechanics in an attempt to arrive at a clearer definition of the factors responsible for brittle fracture. Irwin's analysis led him to propose the specimen shown in Fig. 1. Two engineering measurements derive from Irwin's analysis are:

1. Gc, the value of the energy necessary for rapid crack extension.
2. σx, net section stress.

In the test, notches of subcritical length are loaded at a constant rate of 10,000 lb per min. A marking fluid is applied to the ends of the notches. As the crack extends slowly under load, the fluid flows into the advancing crack front. At the onset of rapid crack propagation, however, the ink no longer can flow fast enough to stain the surfaces. Thus the rapid (brittle) fracture surface remains unstained. The unstained

JOSEPH J. WARGA is in the Materials Research and Development Dept., Aerojet-General Corp., Sacramento, Calif.

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* Notches, not shown, at each end of specimen are about 0.015-in. long and 0.002–0.065 in. wide with 0.005–0.0075-in. radius.

Table 1—Fracture Toughness of Ultrahigh-strength Steels

Material	Thickness, in.	Yield strength, ksi	Net section stress, ksi	Fracture energy, in.-lb/sq in.
AGC X-7	0.080	231	257–267	1680–1800
Tricent	0.080	232	143–202	486–785
Vascojet 1000	0.080	239	98–104	240–284
MBMC#1	0.050	236	97–98	243–249
Peerless 56	0.080	220	97–100	236–253
Unimach II	0.080	232	78–110	152–305
Airsteel X-200	0.080	235	69–94	126–232
Mellon X-2	0.095	246	64–70	108–129
AGC M255	0.109	215	214–224	1190–1300
Ladish D6aC	0.080	240	110–243	320–1450

Table 2—Order of Merit of Ultrahigh Strength Steels for $\sigma x/\sigma y = 1$

Material	Yield strength, ksi	Fracture energy, in.-lb/-sq in.
AGC X-7	230	>1500
Ladish D6aC	215	>1200
AGC M255	210	>1150
Mellon X-2	205	>1100
Airsteel X200	195	>1000
Tricent	190	>1000
MBMC#1	190	>800
Vascojet 1000	185	>750
Unimach II	165	>750

area is the area carrying the load at the instant of failure (net section) and the load per unit area of this section is the net section stress (σx).

Discussion

Basic Materials Evaluation

The center notch-tensile test can be used to determine the relative merit of different materials for use in rocket chambers at a specific level of yield strength. Table 1, for example, shows the results obtained in the testing of several different air-melted alloy steels to meet the requirements of a chamber designed to a minimum yield strength of 230,000 psi. The materials are listed in decreasing order of energy required to propagate a crack, although there may be some question about the order of MBMC #1 and Mellon X-2 because of the differences in sheet thickness compared with the other steels tested. For comparison purposes, at the bottom of the table are listed results obtained with Aerojet-General Specification M255 steel and Ladish D6aC, currently in use for chambers designed to a yield strength of 210,000 psi.

When comparing steels on the basis of fracture energy, the following question naturally arises: What limiting value of *Gc* would suffice to make a steel suitable for use at any desired strength? Is it 750, 1000 or 1500 in.-lb per sq in.? The answer is not yet known. However, Irwin, Kies and Smith[6] show that the net section stress increases as the crack length decreases. If it be assumed that the crack length becomes critical when the net section stress is equal to the yield strength of the material and if it be assumed that the material will yield rather than fracture when cracks less than the critical size are present, it is possible to set limiting values of fracture energy for the materials under

Table 3—Effect of Temperature on Fracture Toughness of 0.220-in. Thick M255 Steel

Tempering temperature, °F	Testing temperature, °F	Yield strength, ksi	Net section stress, ksi	Fracture energy, in.-lb/sq in.
500	70	215	220	1200
...	200	205	205	1100
...	400	180	185	850
825	70	190	190	950
...	200	180	190	900
...	400	165	185	875

Table 4—Rolling Direction Vs. Fracture Toughness

Material	Sheet thickness, in.	Direction of test	Yield strength, ksi	Net section stress, ksi	Fracture energy, in.-lb/sq in.
AMS 6434	0.080	Longitudinal	218	200	>900
	...	Transverse	210	100	235–275
	...	Longitudinal	207	205	>985
	...	Transverse	210	100	218–305
4340	0.080	Longitudinal	203	205	>1000
	...	Transverse	205	85	184–187
	...	Longitudinal	182	195	>900
	...	Transverse	183	95	203–258
X200	0.080	Longitudinal	170	210	1140–1220
	...	Transverse	175	190	889–1200
M255 steel	0.109	Longitudinal	220	210	1190
	...	Transverse	220	170	610
	...	Longitudinal	185	195	1000
	...	Transverse	185	210	1180

Table 5—Fracture Characteristics of Titanium Alloy B120VCA

Treatment	Thickness, in.	Yield strength, ksi	Net section stress, ksi	Fracture energy, in.-lb/sq in.
Solution annealed; aged 900° F, 90 hr	0.072	170	62	197–235
Solution annealed; aged 900° F, 90 hr; aged 1100° F, 15 min	0.072	152	125	774–844
Solution annealed; aged 900° F, 90 hr; aged 1100° F, 15 min; aged 700° F, 48 hr	0.072	154	95	350–425
Solution annealed; aged 900° F, 70 hr; aged 1100° F, 15 min	0.072	150	150	927–1150
Solution annealed; cold reduced 30%	0.051	165	200	>1500
Solution annealed; cold reduced 30%; aged 900° F, 20 hr	0.051	...	54–60	152–194
Solution annealed; cold reduced 40%	0.043	180	148	>1000
Solution annealed; cold reduced 40%; aged 900° F, 20 hr	0.043	...	39–45	73–103

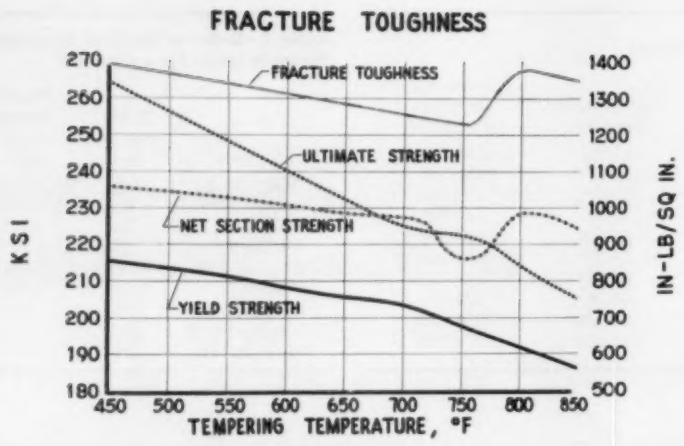

Fig. 2—Fracture properties of M255 steel

study. The limiting value, then, would occur when the ratio of net section stress to yield strength is 1. This argument, while not scientifically precise because of the arbitrary determination of the engineering yield strength, makes it possible to compare the potential usable strength of materials.

Table 2 shows the strength levels at which each of the air-melted materials tested satisfies this requirement, which thus represents the highest yield strength at which each material may be reliably used *at the present time*. Data being collected indicate that great advances are possible in fracture toughness by technological advances in the alloying, melting, manufacturing and heat treatment of steel.

Original subscale and full-scale chamber test results correlate well with the results shown in Tables 1 and 2. Subscale chambers of X-200 and Vascojet 1000 steel and full-scale chambers of Peerless 56 and Tricent have failed in hydrotest at values corresponding to one-half the yield strength when heat treated to 230,000 psi yield strength. Subscale chambers of X-200 and full-scale chambers of Vascojet 1000 have successfully passed hydrotests when heat treated to 190,000 psi yield strength. Many chambers of M255 steel have been fabricated to 210,000 psi yield strength and have successfully passed hydrotests. On the other hand, it has been reported that MBMC#1 has successfully passed hydrotesting when heat treated to 250,000 psi yield strength. However, until more data are available on the material used for these chambers, it is the author's opinion that decarburization was present and influenced the results. Decarburization has been encountered in our own testing. Where it occurs with only limited effects on yield strength, it increases the amount of deformation and the bursting strength that the steel can withstand.

The effect of increasing test temperature on the resistance to crack propagation is shown in Table 3, wherein are described the results obtained with M255 steel. The same effect has been noted with 4132H steel. Material in two separate tempering conditions was tested; although the net section strength and fracture energy decreased with increasing temperature, the yield strength decreased more rapidly. The net effect was an increase in the ratio $\sigma x/\sigma y$ and a consequent increase in toughness, as might be expected from observations with other conventional tests. Further work is being conducted at subzero temperatures.

Evaluation of Processing Variables

Effect of Rolling Direction. Sheet stock may vary in mechanical properties depending on whether samples are tested in the direction parallel to or transverse to the final rolling direction. Table 4 shows the results obtained with four different air-melted steels and illustrates the effect on fracture toughness. Cross rolling, if present, did not equalize the properties. The material listed as M255 steel is a modified AMS 6434.

Effect of Heat Treatment. Heat treatment has a noticeable effect on the properties of steel. The ultimate tensile strength and yield strength decrease with increasing tempering temperature while the elongation, reduction of area and impact resistance generally increase. One phenomenon that has been extensively reported in the literature has been temper embrittlement, which causes lowered ductility at intermediate tempering temperatures. Figure 2 is a set of curves illustrating the fracture characteristics of M255 steel quenched from 1625° F and tempered over the range between 450° and 850° F. Although it is slight, an apparent region of embrittlement is indicated in the region of 750° F. The decrease in temper embrittlement of this steel over AMS 6434 is attributed to the low amounts of sulfur and phosphorus present, and work is under way to investigate the future improvements in embrittlement that may occur in vacuum consumable arc-melted steels.

Precipitation-hardening alloys are well suited to the investigation of the effects of heat treatment on fracture characteristics. Table 5 illustrates how the fracture toughness of titanium alloy B120VCA may be varied by modifications of the precipitation heat treatment. Although a high elongation is obtained in the tensile specimens by a stress relief at 700 F for 48 hr after the two-step aging treatment, it is

Table 6—Effect of Melting Technique on High Strength Steels

Material	Melting process	Thickness, in.	Yield strength, ksi	Net section stress, ksi	Fracture energy, in.-lb/sq in.
AMS 6434	Air	0.080	218	200	>900
	Vac. ind.	0.080	208	100–143	227–466
	Cons. elect.	0.080	221	236–242	1460–1520
4340	Air	0.080	203	205	>1000
	Vac. ind.	0.080	213	224–239	1130–1300
	Cons. elect.	0.080	210	231–244	1390–1540
Tricent	Air	0.080	232	143–202	486–785
	Cons. elect.	0.080	231	115–157	349–632
Airsteel X200	Air	0.080	235	69–94	126–232
	Cons. elect.	0.080	255	107–117	300–342
Unimach II	Air	0.080	232	78–110	152–305
	Cons. elect.	0.080	245	112–132	314–457

Table 7—Comparison of Welding Processes for M255 Steel

Process	Thickness, in.	Yield strength, ksi	Net section stress, ksi	Fracture energy, in.-lb/sq in.
Base material	0.220	199	157	660
Submerged arc	0.200	183	103–149	261–553
Tungsten arc	0.200	189	213–241	>1150

Table 8—Effect of Shear Spinning on Fracture Toughness

Material[a]	Condition	Thickness, in.	Yield strength, ksi	Net section stress, ksi	Fracture energy, in.-lb/sq in.
4340	Unspun (L)	0.085	185	192–214	946–1167
...	Spun—radial	0.094	186	192–201	904–1050
...	Spun—axial	0.094	186	198–206	973–1091
AMS 6434	Unspun (L)	0.095	190	192–212	920–1100
...	Spun—radial	0.092	195	190–203	931–1000
...	Spun—axial	0.092	194	186–204	890–1060

[a] Stress relieved and heat treated

Table 9—Fracture Properties of AGC Development Alloys

Material	Thickness, in.	Heat treatment	Yield strength, ksi	Net section stress, ksi	Fracture energy, in.-lb/sq in.
X-6	0.080	1675° F, oil quench			
		temper 400° F	223	255–266	1550–1710
...		500° F	226	232–265	1300–1700
...		600° F	230	256–264	1590–1690
...		700° F	224	236–253	1150–1300
X-7	0.080	1675° F, oil quench,			
		temper 400° F	227	259–270	1610–1700
...		500° F	227	251–258	1620–1700
...		600° F	232	257–267	1680–1800
...		700° F	231	257–260	1630–1660
X-9	0.080	1650° F, oil quench,			
		temper 400° F	219	259–261	1600–1610
...		500° F	228	250–255	1560–1625
...		600° F	229	252–262	1390–1460
...		700° F	231	141–181	400–600

clearly demonstrated that the resistance to crack propagation is lower. The effect of the additional strength imparted by cold or warm-working between solution-annealing and precipitation-hardening has also been investigated. Table 5 further demonstrates that it may be advantageous to cold work this alloy to obtain high fracture toughnesses at high yield strengths.

Effect of Melting Practices. Vacuum-melting results in decreased gas content and lesser nonmetallic inclusions than can be obtained in air-melted steels. The effect of this increased cleanliness on the fracture characteristics of some steels is illustrated by Table 6. The materials tested were prepared by vacuum-induction and vacuum-consumable-electrode techniques. In general, the resistance of the steels to crack propagation has been improved by the use of vacuum-consumable-electrode melting, although the results obtained with Tricent steel indicate that other processing variables must be closely controlled in order to realize the full improvement possible with vacuum-melting.

Effect of Welding. Welding is a common method of fabrication for steel. In welding, however, the possibility of metallurgical notches arises because of the very nature of the process. Three distinct zones are present in a weld—the weld itself, the heat-affected zone on each side of the weld, and the parent metal. Gas inclusions, slag inclusions, metallic inclusions and interstitial gases may all be present depending on the specific welding techniques employed. Table 7 illustrates the effect of two different welding processes on the resistance to crack propagation of welded

Table 10—Chemical Composition (%) of Steels Tested

Material	C	Mn	Si	S	P	Ni	Cr	Mo	V	Co
AGC X-7	0.38	0.65	1.65	0.006	0.014	1.38	1.78	0.64	0.075	...
AGC X-6	0.41	1.18	1.21	0.006	0.014	1.22	1.76	0.63	0.072	...
AGC X-9	0.38	1.49	1.53	0.006	0.013	0.47	1.80	0.65	0.071	...
Mellon X-2	0.41	0.64	0.54	0.014	0.012	0.15	1.23	0.27	0.22	1.03
Airsteel X200	0.44	0.93	1.20	0.020	0.012	...	2.22	0.39	0.075	...
Tricent	0.43	0.86	1.35	0.031	0.015	1.88	0.86	0.30	...	...
MBMC #1	0.41	0.65	1.51	0.019	0.011	...	0.73	...	0.03	...
Vascojet 1000	0.41	0.36	0.95	0.016	0.015	...	5.55	1.21	0.53	...
Unimach II	0.50	0.35	0.96	0.005	0.011	1.38	5.00	1.22	0.95	...
Peerless 56	0.40	0.65	0.98	0.016	0.010	...	3.00	2.88	0.32	...
4340	0.41	0.67	0.35	0.011	0.008	1.75	0.77	0.23	0.09	...
AMS 6434	0.36	0.73	0.33	0.015	0.019	1.78	0.86	0.31	0.19	...
AGC M255	0.37	0.70	0.55	0.012	0.008	1.70	0.88	0.30	0.19	...
Ladish D6aC	0.46	0.67	0.26	0.014	0.010	0.57	1.05	1.02	0.07	...

M255 steel. Tungsten-arc welding techniques are demonstrated to be clearly superior to submerged-arc techniques at high yield strengths when the same weld wire is used during each of the two processes. In a properly made tungsten-arc weld, there is no apparent difference in resistance to crack propagation between the weld zone and the heat-affected zone, based on observations of fractured surfaces.

Flash welds have been studied only briefly, and observations of crack size and pressure at failure indicate values lower than for submerged-arc welds when an air-melted steel is used. This has been associated with outflow of the fibers during the upsetting at the end of the flash-welding cycle.

Effect of Shear-Spinning. One attractive method of fabricating the cylindrical portion of rocket chambers is shear-spinning. As the name implies, forming is accomplished by lateral deformation under constant pressure applied through a work roll while the material to be deformed is rotated. Either forged or welded sheet annular preforms are used to fabricate cylindrical sections. Table 8, listing results obtained on AMS 6434 and 4340 steels, demonstrates that shear-spinning when properly performed has no deleterious effect on the basic material. This might be rationalized by stating that the forming conditions are severe enough to serve as a preliminary evaluation of material.

Alloy Development

The low resistance to crack propagation of the commercially available steels suitable for use at ultrahigh yield-strength levels prompted a development program aimed at producing steels with superior fracture toughnesses. Twenty-four separate compositions were designed, based on observations of the alloying elements that contribute to high fracture characteristics. Table 9 lists the three best of these development alloys. It will be noted that the net section stress and the fracture energy of these alloys is higher than any of the other steels reported in this paper.

The composition of the three best development alloys, as well as the other steels tested, are listed in Table 10.

Summary

Evaluation of materials for solid rocket chamber use by means of the center notch-tensile test proposed by Irwin and Kies has been performed and an order of merit has been established for alloy steels, based on the equivalence of net section stress and yield strength.

Furthermore, the use of the test to determine the effects of heat treatment, rolling, welding, melting techniques and cold-working has been described, and it has been shown that the test is valuable in the selection of processing and fabricating procedures for the manufacturing of rocket chamber materials and the fabrication of chambers.

Finally, it has been shown that alloys can be designed for high specific fracture toughnesses. By inference, the development of alloy steels of high strength combined with high resistance to crack propagation is shown to be feasible.

Acknowledgment

Grateful acknowledgment is made of the many conversations with Dr. George Irwin, Joseph Kies and Dr. William Brown that occurred during the course of the many investigations covered by this paper. The persons concerned in the investigations are many, but particular thanks are due to L. L. Gilbert, J. A. Brown and R. D. Freymeyer of the Aerojet-General Corp., Azusa Material Laboratory, and to J. E. Erb, S. M. Jacobs, R. E. Anderson and P. P. Crimmons of the Sacramento Materials and Fabrication Division.

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Notice—Annual University Research Conference of Welding Research Council

The University Research Committee of Welding Research Council will hold its Annual Conference this year on *Wednesday evening, April 19, 1961 at 8 P.M. in the Windsor Terrace room of the Hotel Commodore, New York City.*

In order to encourage more basic research in welding processes, the Committee has planned a 2-paper symposium on Arc Physics Research. The authors are the world renowned Dr. H. J. Olsen from the United States, and J. C. Amson from England. The Committee cordially invites research men from industry and government agencies, as well as from the universities, to attend this symposium.

Catastrophic Fracture Caused by Ductile-to-Brittle Transition Under Residual Stresses

The results of original studies on molybdenum are presented as a guide toward further understanding the welded behavior of other body-centered-cubic materials with ductile-to-brittle transitions below room temperature

BY W. N. PLATTE

ABSTRACT. These studies describe the use of molybdenum as a means of examining the relationship between transition temperature, residual welding stresses and catastrophic rupture.

It is shown that postweld stress-relief treatments applied before the welds cool below the ductile-to-brittle transition temperature prevent the catastrophic cracking found in the weld crater area.

Introduction

In the past 20 years, investigators have covered many phases of the residual welding stress problem. However, most of these studies were made on materials having a moderate degree of ductility at room temperature. With the exception of welds in special alloys which have a degree of ductility, welds in molybdenum must be considered brittle at room temperature. For example, welds in carbon-deoxidized molybdenum without other alloy additions show ductile behavior in bending only at temperatures above 200 to 300° F. Welds in this material are below the ductile-to-brittle transition temperature when they have cooled to room temperature, and the residual stress problem is influenced by its relation to the ductile-to-brittle transition temperature.

The influence of the ductile-to-brittle transition on residual stress cracking in molybdenum can serve as a useful guide in understanding the welded behavior of other body-centered-cubic metals. The ductile-to-brittle transition phenomenon occurs in Fe, Cr, Mo, W, Nb and V. The relationship between the ductile-to-brittle transition and residual welding stresses in carbon steel has been demonstrated recently by Vinckier, who found it necessary to cool the welded plate to temperatures between −157° and −259° F to induce spontaneous cracking.[1] Spontaneous failures due to residual stresses and reduced temperatures were demonstrated earlier by a number of different workers.[2-5] In molybdenum the transition temperature is above ambient so that cooling to room temperature is sufficient to induce spontaneous brittle fracture.

The present studies were made using the weld specimen shown in Fig. 1. A portion of a 2- × 6-in. plate, 0.065-in. thick, was fused using an inert-gas tungsten arc without filler metal addition. Fusion was started and stopped on the plate so that all the welding stresses were confined. The presence and nature of stresses in the weld crater area in this type specimen have been shown using photoelastic techniques.[6] Many of these bead-on-plate welds made in molybdenum cracked at the weld crater after the samples had cooled. Cracking sometimes occurred violently after the weld had reached room temperature. These results indicated that cracking was due to a combination of residual welding stresses and loss of ductility. In order to gain some insight into the nature of these phenomena, the stresses at the weld crater were measured.

A welding technique and heat treatment were developed to remove the residual welding stresses before the weld had cooled below the transition temperature. Through the use of this technique, it is possible to show that the residual welding stresses could be removed and spontaneous cracking eliminated. The relationship between residual welding stresses and the ductile-to-brittle transition is also established using this technique.

Experimental Data and Results

Arc-cast molybdenum, deoxidized with carbon, was used in these studies. The carbon content of the material was 0.04%. Previous work had shown that the ductile-to-brittle transition temperature in bending for welds in this material was 300° F.[7-9] This material was also found to be subject to cracking at the weld crater in a large percentage of the weld samples made. Hence, if postweld stress relief is used on welds in this material prior to cooling below the transition temperature, the elimination of crater cracking is a qualitative indication of the removal of welding stresses. Furthermore, elimination of postweld cracking in this material by the stress-relieving treatments used relates the cracking phenomenon to the ductile-to-brittle transition temperature.

Welds in molybdenum must be made without contamination from oxygen or nitrogen if the transition temperature is to remain a function of the original material composition.[10,11] Very small amounts of

W. N. PLATTE is with the Metals Joining Section, Metallurgical Department, Westinghouse Research Laboratories, Pittsburgh, Pa.

oxygen or nitrogen contamination in the weld metal will cause a loss in ductility and brittle-fracture strength.[7,8] To prevent ductility changes due to contamination, welds were made in a welding chamber using a carefully controlled inert-gas atmosphere; and protection was provided during postweld heat treatment.

Welds were made on seven specimens using a welding chamber filled with argon.[7] The welding speed was 6 ipm, and the current was 180 amp at 12–14 v. Welds were made in pairs; one weld from each pair was heat treated, and the second weld was cooled to room temperature as a control. One additional weld was made, stress relieved at 1832° F, and held at room temperature to determine the ambient temperature cracking tendencies.

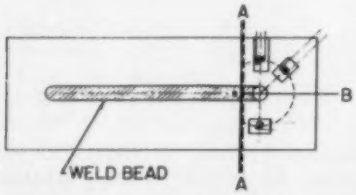

Fig. 1—Location of strain gages for determining residual weld stresses

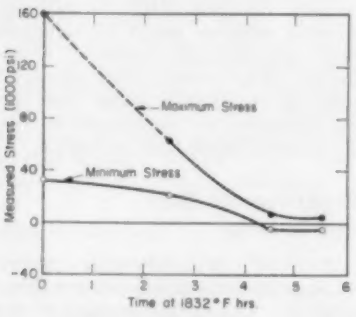

Fig. 2—Measured tensile stresses vs. time at temperature

Table 1—Treatment Times and Temperatures

Sample	Time at temperature, hr	Heat-treating temperature, ° F
SR1A	...	None
SR1	$2^1/_2$	1832
SR4A	...	None
SR4	$4^1/_2$	1832
SR2A	...	None
SR2	5	1832
SR3	3	1832

Heat treatment was done in a bottom-loading vertical-vacuum furnace. The furnace was evacuated to 1×10^{-5} mm Hg and heated to 1832° F. When the furnace was at temperature and just before the weld was started, the furnace was filled with helium and the bottom was opened. The weld was made and removed from the welding chamber and placed in the hot zone of the furnace. Protection was provided for the furnace and weld by the helium. Twenty seconds elapsed between completion of the weld and its entry into the hot zone of the furnace. When the weld was in position, the furnace was closed and evacuated to 1×10^{-5} mm Hg. Heat treatment, at 1832° F, varied between $2^1/_2$ and 5 hr. The samples and the heat treatments used are given in Table 1.

Test plates were held at room temperature for about two weeks. During this time the welds were not touched. At the end of the two-week period, two of the three welds which had not been stress relieved had cracked. One of the welds cracked with considerable violence. Cracking of this type can occur as a result of room temperature variations. However, none of the heat-treated samples failed.

Table 2—Residual Welding Stresses

Sample	Treatment—Temp., ° F	Treatment—Time, hr	Maximum stress, psi	Minimum stress, psi
SR1A	None	...	160,000[a]	32,000
SR1	1832	$2^1/_2$	63,000	21,000
SR4	1832	$4^1/_2$	6,800	—4,000
SR2	1832	5	4,500	—4,700

[a] Weld ruptured through one gage during cutting; value estimated from other readings.

Four of the remaining samples were used to measure the residual welding stresses in the region of the weld crater. The measurements were made with Type C7 strain gages and standard resistance measuring equipment. The gage configuration used is shown in Fig. 1. The resistance of the gages was measured after cutting and the stresses were calculated. The principal stresses in the weld crater area are given in Table 2. Weld SR3, Table 1, was held at room temperature for two years after heat treatment. No cracks developed during this time.

Discussion

The results given in Table 2 are also shown in Fig. 2. The data indicates biaxial tension after welding. The stress-relief heat treatment removed the stresses in both directions. Prior data obtained on the same material showed that the proportional limit of welds varied with temperature according to the curve in Fig. 3. These data indicate that the proportional limit is approximately 85,000 psi at room temperature. It is difficult to explain the incompatibility of the stresses measured on the welds and the proportional limit data. The possibility of the biaxial stress pattern shifting the fracture characteristics was considered as one explanation. Felbeck and Orowan[12] state that the ductile-to-brittle transition, the strain rate, and the triaxial stress condition determine the nature of the fracture. Triaxial stresses apparently make it possible to reach the fracture strength before sufficient yielding has occurred for ductile fracture. However, the system involved in these studies was

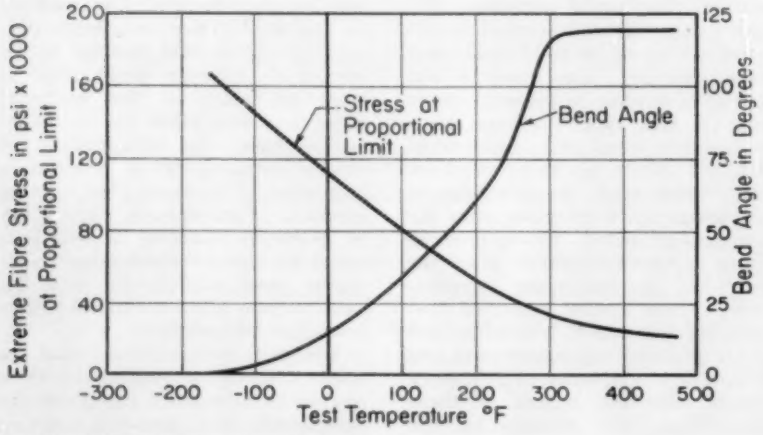

Fig. 3—Relation of stress at proportional limit and bend angle to test temperature

Fig. 4—Catastrophic failure of molybdenum weld

biaxial and yielding although the sheet thickness should have occurred unless the yield strength was higher than indicated by the proportional limit data in Fig. 3. It is known that increased strain rates will cause the ductile-to-brittle phenomena to shift to higher temperatures.[13] However, the strain rate in these experiments was very low. The effect would be similar to room temperature creep or stress rupture and the effect of strain rate on transition phenomena should be small.

It is apparent that if the proportional limit curve was shifted to higher temperatures, stresses of the magnitude found around the weld craters could exist. It should be emphasized that the ductile-to brittle transition phenomena are dependent on the method of testing. Any shift in the test procedure may result in a shift in the numerical value of the transition temperature. The data in Fig. 3 were obtained by bending ground weld metal samples transverse to the direction of welding. The fact that the welds used in the present studies did not have ground surfaces could easily have shifted the transition temperature to higher values. Such a shift would necessitate shifting the proportional limit curve in Fig. 3 with respect to the temperature coordinate. A shift of +150 to +170° F would permit stresses of the magnitude measured to exist. The difference between the experimental test methods used to determine the curve in Fig. 3 and the actual sample could be large enough to produce such a shift.

Regardless of the actual mechanism involved, stresses approaching the fracture strength were indicated by the violent nature of the fractures which occurred when the specimens were allowed to stand at room temperature. Figure 4 shows a fracture in which the end portion of the weld moved 18 in. Similar fractures may occur in molybdenum welds if the specimens are touched, slightly stressed or subjected to a sudden 5° to 10° F drop in room temperature. The presence of stresses near the fracture strength is apparent from these events and on this basis the stresses shown for the untreated weld in Table 2 are probably real. At this time the only explanation seems to be a shift in the stress at the proportional limit curve to higher temperatures although the reason for this shift is not fully understood.

The relationship between the residual welding stresses and the ductile-to-brittle transition in molybdenum welds indicates the use of stress relief techniques which can be applied before the weld has cooled below the ductile-to-brittle transition temperature. The residual welding heat was used to prevent cracking in these experiments. However, in most fabrication processes, this technique would not be practical. The same result may be accomplished by keeping the weld above the transition temperature through the application of heat from an external source until the stress relief treatment can be started. Preheating to temperatures at or above the transition temperature can be used on sections heavy enough to cause a quenching effect on the weld. Preheating would have to be followed by postweld heating until the part could be stress relieved. In general, any technique which permits the removal of residual welding stresses before the weld area has cooled below the ductile-to-brittle transition temperature should be successful in preventing the type of cracking shown in these studies.

The magnitude of the stresses found in the relatively simple test specimens used indicates a need for extensive study of residual stress patterns around welds. If stresses of the magnitude and type shown in this work can exist in welded structures, it is obvious that the stresses should be known and the effect of the ductile-to-brittle transition temperature taken into account. The elimination of the residual welding stresses before the part has cooled to the transition temperature is imperative.

Summary

Residual welding stresses can be encountered which are sufficient to produce catastrophic cracking at room temperature in molybdenum welds. Cracking is caused by the combination of high stress and loss of ductility as a function of temperature. While molybdenum welds are an extreme example, similar cracking could occur in other materials of the BCC group. Cracking due to loss in ductility with reduced temperature and residual welding stresses can be eliminated if the stresses are removed before the weld area has cooled below the transition temperature.

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Theory of Brittle Crack Initiation and Propagation—A Theoretical Analysis of ESSO Test

Information is developed from the viewpoint of dynamics on the effects of impact energy, temperature yield stress and plastic surface energy on brittle crack initiation and propagation

BY YOSHIO AKITA AND KAZUO IKEDA

ABSTRACT. Brittle crack initiation and propagation are investigated theoretically from a viewpoint of dynamics. A dynamically modified Griffith-Orowan energy condition, in which the effect of crack speed on rates of released elastic strain energy and kinetic energy are taken into account, must be satisfied for brittle crack initiation and propagation. The rate of plastic work done, caused by yielding around the tip of a crack, must also be considered for crack initiation. The ESSO test, in which tension and impact are needed for crack initiation, can be interpretated by this theory.

Introduction

The theory of brittle fracture was initially studied on the basis of energy condition by Griffith,[1,2] and then developed by Orowan,[3,4] Irwin,[5,6] Wells,[7] Roberts and Wells,[8] Boyd,[9] Mott,[10] and Yoshiki and Kanazawa[11] by applying the statical stress distribution in a stretched plate containing a crack. The effect of residual stress on the brittle fracture was investigated by Kihara and Masubuchi.[12]

In general, a brittle crack propagates at high speed. Therefore, the phenomenon of brittle fracture must be investigated dynamically. Yoffe[13] has studied the dynamical stress field near the tip of a moving Griffith crack of constant length at high speed. Craggs,[14] Gaus,[15] and the authors[16-18] have studied the dynamical stress field around an expanding crack.

Experimentally, Wells and Post,[19] Hall, Rolfe, Barton and Newmark[20] and the authors[21] have investigated the correlation between the dynamical stress field the crack speed. Further, the authors have studied the correlations between the crack length, the temperature, the applied uniform stress, the plate thickness and the crack speed, and subsequently the correlation between the plastic surface energy and the temperature.

In this report, the authors have developed a theory of brittle crack initiation and propagation from a viewpoint of dynamics. This theory is applied to the ESSO test.

Energy Condition

The Griffith's energy condition, in which the released elastic strain energy rate is equal to the rate of work done which is required to create new surfaces as a crack extends under a uniaxial tensile stress, is expressed by

$$\pi p^2 l/E = 2S \qquad (1)$$

where p, l, E and S are the uniaxial tensile stress, the half-crack length, Young's modulus and the surface energy, respectively.

Irwin[5] and Orowan[3] have found that the work done in a plastically deformed thin layer adjacent to the fracture surface is much greater than the surface energy and, therefore, the plastic surface energy must be substituted for the surface energy. In addition, the brittle fracture that occurs at approximately room temperature is accompanied by a shear lip. Therefore, the plastic strain energy has to be taken into account in addition to the plastic surface energy.

The plastic surface energy is the most important factor related to the brittle strength of material and was estimated by Orowan[3] from X-ray measurements of the distorted thickness beneath the fracture surface, and by Wells[7] from measurements of temperature near the propagating crack. In addition, a method of estimating the plastic surface energy was proposed by the authors from crack speed measurements.[21]

The correlation between the plastic surface energy and the temperature which has been obtained by using the ESSO test specimen is shown in Fig. 1 and expressed by

$$S = A \exp(-k/T) \qquad (2)$$

where T is absolute temperature in K, and A and k are material constants. From the correlation between log S and $1/T$, k can be obtained. As an example, A = 3.8 x 10^3 kg-mm/mm^2 (1.8 x 10^4 ft-lb/in.^{2}) and k = 2.3 x 10^3 K for a normalized killed steel—Curve Al in Fig. 1. The chemical compositions and the tensile properties of steels tested are shown in Table 1.[21]

Equation 1 represents the energy condition for a statical case. However, one of the most significant characteristics of the brittle crack propagation is the fact that the crack propagates at high speed.

The authors[18] have solved the dynamical equation for a slit enlarging at constant speed under a uniaxial tensile stress at infinity. In addition to elliptical coordinates, a new conception of expanding coordinates in which the coordinates expand or enlarge with time (Fig. 2) is applied to solve the equation.

The stress distribution at any time along the slit line for various crack speed ratios is shown in Fig. 3. The ordinate is a ratio of stress in the direction normal to the slit to the uniaxial stress, and the abscissa is a ratio of the distance from the center of crack to a half-crack length. X = 1 represents the tip of a

YOSHIO AKITA is Head of Ship Structure Div., Transportation Technical Research Institute, Tokyo, Japan; KAZUO IKEDA is Head of Vibration Section, Ship Structure Div., Transportation Technical Research Institute and is presently a Visiting Research Fellow in the Dept. of Civil Engineering, University of Illinois, Urbana, Ill.

Table 1—Chemical Compositions and Tensile Properties

Steel	Kind of steel	Thickness mm	Thickness in.	Chemical compositions, % C	Mn	P	S	Si	Cr	Ni	Cu	Mo	V	Al	B	Tensile properties: Yield point Kg/mm²	Yield point Ksi	Tensile strength Kg/mm²	Tensile strength Ksi	Elongation, %	Note
A 1	Normal-	30	1³/₁₆	0.13	1.13	0.025	0.017	...	0.06	0.06	0.19	...	...	...	...	32.4–32.6	46.1–46.4	47.6–47.9	67.7–68.2	36.5–36.8	...
A 2	ized	45	1³/₄	0.13	1.14	0.023	0.019	...	0.05	0.06	0.18	...	...	...	...	32.9	46.8	48.8	69.4	33.6	...
A 3	Killed	50	2	0.13	1.16	0.023	0.020	...	0.07	0.05	0.20	...	...	...	...	28.8–29.4	41.0–41.8	45.2–46.5	64.3–66.2	27.5–35.1	...
B	Quenched	30	1³/₁₆	0.16	1.25	0.016	0.012	...	0.11	0.05	0.20	...	...	...	...	52.4	74.6	61.7	87.8	24.0	...
C	and	13	½	0.14	0.77	0.020	0.021	0.29	0.58	0.80	0.36	0.52	0.05	0.02	...	70.3[a]	100.0	80.9–94.9[a]	115.1–135.0	18[a]	...
D	tempered	12	½	0.14	0.95	0.014	0.016	0.24	0.54	0.90	0.24	0.53	0.08	0.02	0.0022	72	102.5	79	112.4	17	Gage length 200 mm, 8 in.
																72.3	102.9	78.5	111.7	29	Gage length 50 mm, 2 in.

[a] By the manufacturer's specifications.

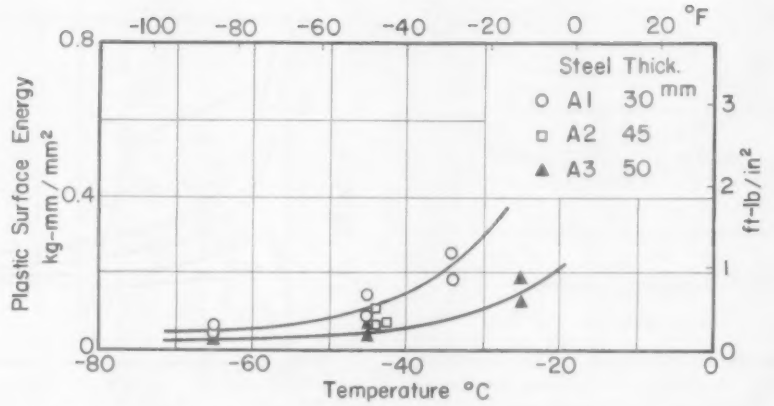

Fig. 1—Correlation between plastic surface energy and temperature

moving crack. The crack speed ratio is a ratio of crack speed to the speed of sound or to the propagating speed of plane longitudinal waves. Since the radius of the propagating wave fronts for a crack enlarging at the crack speed ratio of V/c is c/V, the curve for $V/c = 0.4$ extends to $X = 2.5$. As the crack speed increases the dynamical stress around the propagating crack decreases as shown in Fig. 3. The radius of propagating wave fronts decreases also. Therefore, the released elastic strain energy rate due to the crack extension decreases with increased crack speed. Further, the rate of kinetic energy, due to the partial displacement with time, increases with increased crack speed.

The following equation has been previously proposed by the authors[21] as the dynamically modified energy condition for brittle crack propagation

$$\frac{\pi p^2 l}{E(1 + m\alpha^2)^2} = 2S \qquad (3)$$

where m was determined experimentally and found to vary from 70 to 140. Although S is a function of the material properties, the temperature and the crack speed (or the strain rate), even for a brittle crack without a shear lip, it may be assumed that the effect of crack speed is covered by the denominator on the left hand side of eq 3. Therefore, S is the plastic surface energy for low crack speed without a shear lip. Equation 3 is shown schematically in Fig. 4, in which the abscissa is the distance from the free edge of the specimen to the tip of a propagating crack. It can be seen in Fig. 4 that the $l-\alpha$ curve starts from a point, which has a crack length of l_G, and the crack speed increases with crack length. However, the rate of change in crack speed decreases. Test results generally show that the crack speed ratio α is lower than 0.3.

In Fig. 4, the $l-\alpha$ curve shifts to the left as the uniform stress increases, and consequently the starting point of the curve might be the tip of the notch. Although eq. 3 is satisfied in this case, a crack cannot initiate and propagate. The $l-\alpha$ curve for low crack speeds is represented by the dashed curve. This represents the situation when the plastic deformation around the tip of the crack is taken into account as stated in the following paragraph. The crack length for $\alpha = 0$ eq 3 is l_G, which satisfies the statical Griffith-Orowan energy condition, and is represented by

$$l_G = 2ES/\pi p^2 \qquad (4)$$

As mentioned above, a crack cannot initiate even though l_G is equal to the notch depth. Using normalized killed steel as an example, when the temperature is $-45°$ C($-49°$ F), S = 0.15 kg-mm/mm²(0.70 ft-lb/in.²), $p = 5$ kg/mm²(7.1 ksi), l_G becomes 80.8 mm (3.18 in.).

Energy Condition Including the Effect of Shear Lip

A shear lip can be found on a fracture surface at high-temperature or low crack speed. When a shear lip is found, the plastic work done has to be taken into account. If the x-axis is taken parallel to the direction of the propagating crack as shown in Fig. 5, the stress normal to the direction of the crack (σ_β) along the crack line is approximately expressed by the following equation

$$\sigma_\beta = p\,\frac{\sqrt{l/2x}}{(l + m'\alpha^2)} \qquad (5)$$

The denominator, $(1 + m'\alpha^2)$, shows that the stress concentration decreases as the crack speed

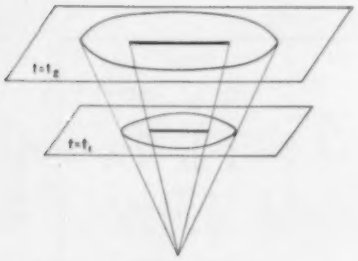

Fig. 2—Expanding coordinates

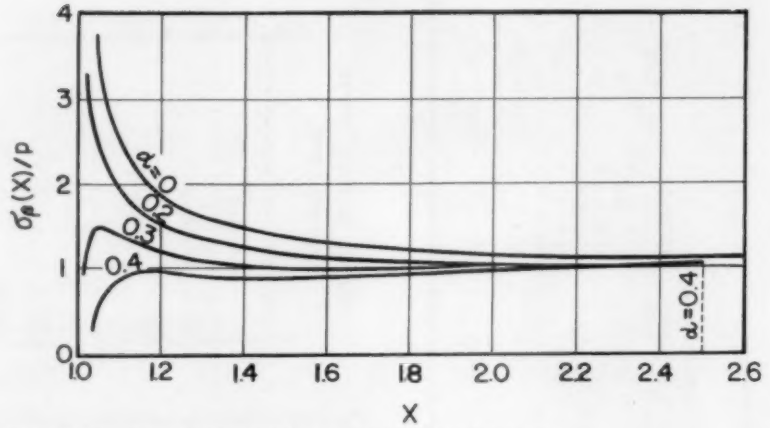

Fig. 3—Distribution of stress ratio σ_β/p along the crack line for various crack speed ratios

ratio, α, increases. The constant, m', is about 100 as the results of calculation by the authors.

Although the stress becomes extremely large at the tip of a crack, the tip of the crack is assumed to be located at $x = x_1$, and the stress at this point is $\sigma_{\beta 1}$ (Fig. 5), if we consider that the plastic work done as suggested by Orowan can be found in the region very close to the fracture surface.

Let one consider the case in which the shear lip or a yield zone is found in the vicinity of the tip of the crack. The stress distribution is assumed to be approximately the same as obtained originally without yielding. Taking the point $x = x_2$ where the stress σ_β is equal to the yield stress, σ_Y, a yield zone is found in the region between x_1 and x_2 in Fig. 5 and the fracture surface is accompanied by a shear lip. Therefore, yielding occurs when

$$\sigma_{\beta 1} \geqq \eta \sigma_Y \qquad (6)$$

where σ_Y is the yield stress under uniaxial tension and is a function of strain rate, n is a coefficient of increasing yield stress under multiaxial tension around the tip of a crack. In fact, n is nearly equal to 3 at the middle of plate thickness and to unity on the rolled surface. Therefore, n is assumed to have values which vary from 1.2 to 2 if the phenomenon is averaged in the direction of plate thickness.

At any time the yield zone can be found in the region in which the diameter is equal to h $(= x_2 - x_1)$ and moves forward with a width of h as the crack progresses.

Now, let one calculate the plastic work done at x_1. The stress at x_1, $\sigma_{\beta 1}$, can be expressed from eq. 5 by

$$\sigma_{\beta 1} = p \frac{\sqrt{l/2x_1}}{(1 + m'\alpha^2)} \qquad (7)$$

The plastic strain is expressed as shown in Fig. 6 by

$$\epsilon = OC \cong (\sigma_{\beta 1} - n\sigma_Y)\, b/E \qquad (8)$$

where E/b is the tangent modulus in the plastic region for the simplified stress-strain diagram and its value varies from 3 to 7. Since Fig. 6 shows that

$$\square OABC \cong \square OADC = n\sigma_Y \epsilon_1$$

the plastic work done per unit volume is represented from eqs 7 and 8 by

$$\delta w_{shear} = \frac{bn^2\sigma_Y^2}{E} \times \left(\frac{p}{n\sigma_Y} \frac{1}{1 + m'\alpha^2} \sqrt{\frac{l}{2x_1}} - 1\right) \qquad (9)$$

The yield zone exists between x_2 and x_1 in Fig. 5. From eq 5 one obtains

$$x_2 = l \frac{(p/n\sigma_Y)^2}{2(1 + m'\alpha^2)^2} \qquad (10)$$

Since the yield zone moves forward with a constant width of h $(= x_2 - x_1)$ at the same speed of the crack (Fig. 5), the rate of total work done is expressed by

$$w_{shear} = \frac{1}{2} \frac{bn^2\sigma_Y^2}{E} \times \left(\frac{p}{n\sigma_Y} \frac{1}{1 + m'\alpha^2} \sqrt{\frac{l}{2x_1}} - 1\right) \times (x_2 - x_1) \qquad (11)$$

Equation 11 is multiplied by the

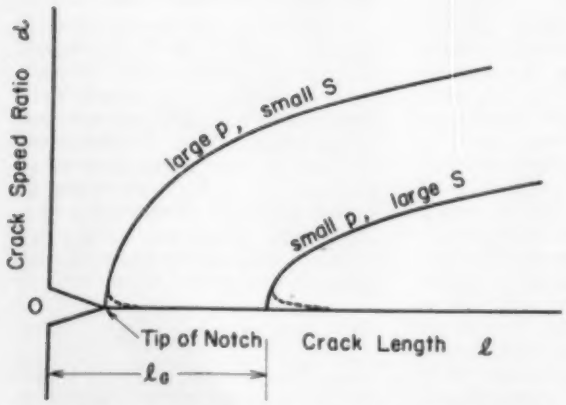

Fig. 4—Correlation between crack speed ratio and crack length

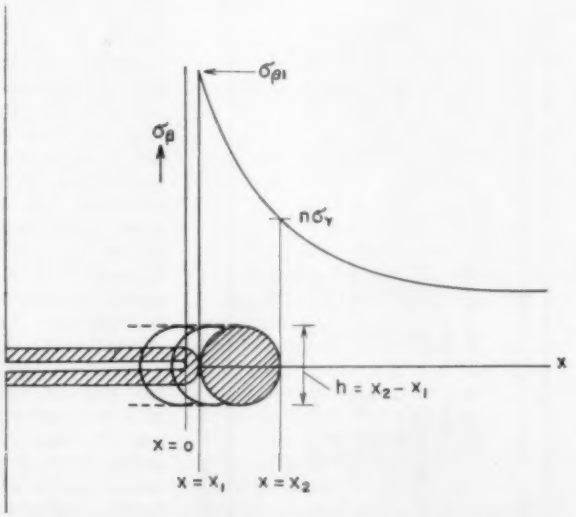

Fig. 5—Stress distribution around the tip of a moving crack

1/2 in order to obtain the mean value of plastic work done in the length of h. From eq 6 which is the yield condition, eq 11 is valid for

$$\frac{1}{1 + m'\alpha^2} \frac{p}{n\sigma_Y} \sqrt{\frac{l}{2x_1}} \geqq 1 \quad (12)$$

and

$$w_{\text{shear}} = 0 \quad (13)$$

for

$$\frac{1}{1 + m'\alpha^2} \frac{p}{n\sigma_Y} \sqrt{\frac{l}{2x_1}} < 1 \quad (14)$$

in which no yield zone exists.

By using eq 7 and neglecting terms greater than δ^3, where

$$\delta = \frac{p}{n\sigma_Y} \frac{l}{1 + m'\alpha^2} \sqrt{\frac{l}{2x_1}} - 1$$

one obtains

$$w_{\text{shear}} = \begin{cases} \dfrac{bn^2\sigma_Y^2 x_1}{E} \left(\dfrac{p}{n\sigma_G} \dfrac{1}{1 + m'\alpha^2} \sqrt{\dfrac{l}{2x_1}} - 1 \right)^2 & \text{for } \dfrac{p}{n\sigma_Y} \dfrac{1}{1 + m'\alpha^2} \sqrt{\dfrac{l}{2x_1}} \geqq 1 \\ & \text{for } \dfrac{p}{n\mathrm{n}_Y} \dfrac{1}{1 + m'\alpha^2} \sqrt{\dfrac{l}{2x_1}} < 1 \end{cases} \quad (15)$$

For the energy condition when the shear lip exists, the energy to be exhausted is the sum of the plastic surface energy S and the plastic work done, w_{shear}, due to the shear lip and is expressed by

$$\frac{\pi p^2 l}{E(1 + m\alpha^2)^2} = \begin{cases} 2S + \dfrac{bn^2\sigma_Y^2 x_1}{E} \left(\dfrac{p}{n\sigma_Y} \dfrac{1}{1 + m'\alpha^2} \sqrt{\dfrac{l}{2x_1}} - 1 \right)^2 & \text{for } \dfrac{p}{n\sigma_Y} \dfrac{1}{1 + m'\alpha^2} \sqrt{\dfrac{l}{2x_1}} \geqq 1 \\ 2S & \text{for } \dfrac{p}{n\sigma_Y} \dfrac{1}{1 + m'\alpha^2} \sqrt{\dfrac{l}{2x_1}} < 1 \end{cases} \quad (16)$$

In order to simplify the expression, one assumes $m' = m$ and defines the nondimensional plastic surface energy by using l_G, which is defined by eq 4, as follows:

$$s = ES/\pi n^2\sigma_Y^2 x_1 \quad (17)$$

and defines

$$L = \frac{l}{l_G(1 + m\alpha^2)^2} \quad (18)$$

Therefore, eq 16 becomes

$$L = \begin{cases} 1 + \left(\sqrt{L} - \dfrac{1}{\sqrt{s}} \right)^2 \dfrac{b}{2\pi} & \text{for } \sqrt{L} \geqq \dfrac{1}{\sqrt{s}} \\ 1 & \text{for } \sqrt{L} < \dfrac{1}{\sqrt{s}} \end{cases} \quad (19)$$

Since the value of $b/2\pi$ is nearly equal to unity, one assumes that $b/2\pi = 1$ and obtains

$$L = \begin{cases} \left(\dfrac{1}{\sqrt{s}} + \sqrt{s} \right)^2 / 4 & \text{for } s \geqq 1 \\ 1 & \text{for } s < 1 \end{cases} \quad (20)$$

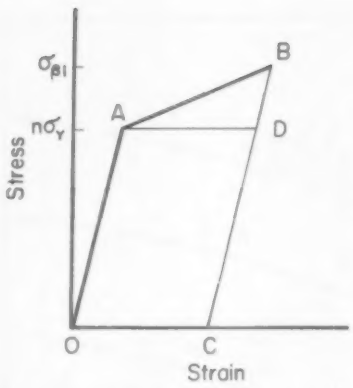

Fig. 6—Stress-strain diagram for $x = x_1$

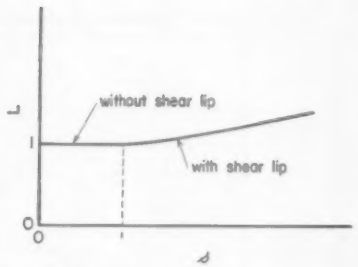

Fig. 7—Correlation between non-dimensionalized crack length and plastic surface energy

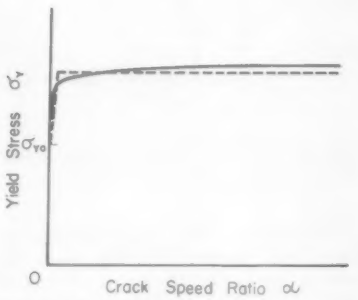

Fig. 8—Correlation between yield stress and crack speed ratio

Equation 20 is shown in Fig. 7, in which the shear lip appears when s is greater than unity. In other words, the shear lip tends to appear as the plastic surface energy increases or the yield stress decreases.

Yielding

It is well known that the yield stress increases with strain rate. As a brittle crack propagates at high speed, the influence of crack speed on the yield stress must be taken into consideration.

Winlock and Leiter[22] give the following equation:

$$\sigma_Y = \sigma_{Y0} + k_2 \log (\dot{\epsilon}/\dot{\epsilon}_0) \quad (21)$$

where σ_{Y0} is the yield stress for $\dot{\epsilon}_0 = 4 \times 10^{-5}$ sec^{-1} which corresponds to the standard condition at low strain rate, and k_2 is a material constant which is, for instance, equal to 1.11 kg/mm^2 for mild steel.

The correlation between the strain rate at $x = x_2$ and the crack speed can be expressed by

$$\dot{\epsilon} = \frac{cp\sqrt{l}}{E(1 + m\alpha^2)(2x_2)^{1.5}} \alpha \quad (22)$$

where c is the speed of sound. Therefore, from eqs 21 and 22 one obtains approximately

$$\sigma_Y = \sigma_{Y0} + k_2 \log (K\alpha/s) \quad (23)$$

where K is a material constant and equal to $cn\sigma_{Y0}/2Ex\,\dot{\epsilon}_0$.

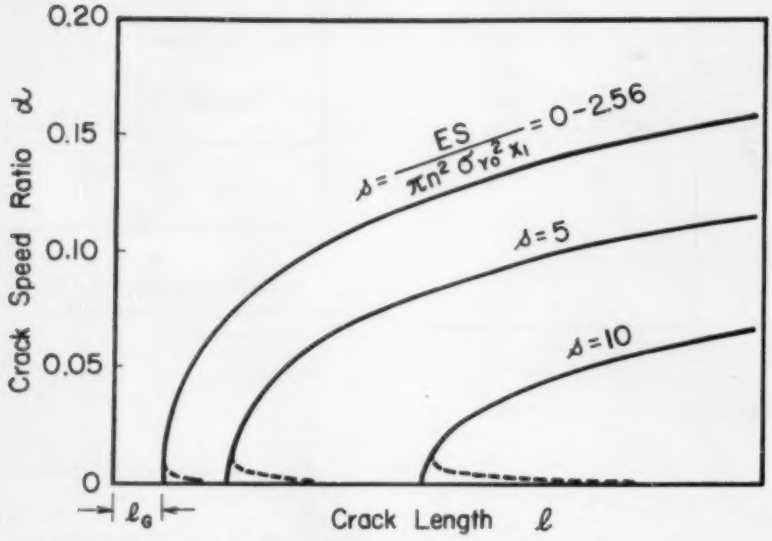

Fig. 9—Correlation between crack speed ratio and crack length for various plastic surface energies

Therefore, the yield stress, σ_Y, increases logarithmically with the crack speed ratio, α, as shown in Fig. 8. Since the yield stress increases greatly in the region of small α, it may be assumed to be a nearly constant value of 1.6 σ_{Y0} for the crack speed ratio of 0.01 –0.3. For simplicity, one assumes that

$$\sigma_Y = \sigma_{Y0} \quad \text{for } \alpha \cong 0$$
$$\sigma_Y = 1.6\,\sigma_{Y0} \quad \text{for } \alpha > 0.01 \qquad (24)$$

By substituting eq 24 into eq 20, the correlation between the crack speed ratio and the crack length is consequently expressed by the following equations:

$$l = l_0 \left(\frac{1.6}{\sqrt{s}} + \frac{\sqrt{s}}{1.6}\right)^2 \frac{(1 + m\alpha^2)^2}{4} \qquad (25)$$

for $ES/\pi\eta^2\sigma_{Y0}^2 x_1 \geqq 2.56$, where the shear lip exists, and

$$l = l_0 (1 + m\alpha^2)^2 \qquad (26)$$

for $ES/\pi\eta^2\sigma_{Y0}^2 x_1 < 2.56$, where the brittle fracture surface has no shear lip. Equations 25 and 26 are shown schematically by a dashed and a solid line, respectively, in Fig. 9. The solid curve shifts to the right as the plastic surface energy increases. It is important to emphasize that s is greater when crack speed ratio $\alpha \cong 0$ due to the low yield stress; this can be seen from eqs 17 and 24, than that for the greater crack speed ratios. Therefore, the $l - \alpha$ curve turns to the right in the region of crack speed ratios near zero which are obtained from eq 25 and shown by a dashed curve in Fig. 9.

In Fig. 10, a crack can initiate when the $l - \alpha$ curve starts under the condition representative by Curve A which starts at a right angle to the abscissa. On the other hand, a crack cannot initiate in the case of Curve B. As a result, a crack cannot initiate under a uniform tensile stress, p, even though l_0 is equal to the notch depth. In other words, it is necessary for crack initiation to increase the yield stress by applying an additional impact or changing metallurgically the steel quality around the tip of the notch.

A Theoretical Analysis of the ESSO Test

The ESSO test requires an impact on a notch in order to initiate a brittle crack which will propagate under suitable conditions for crack propagation. At first, let one study the condition of crack initiation. An application of impact load with a wedge seems to be equivalent to increasing uniform tensile stress around the tip of the notch with respect to the effect on the $l-\alpha$ curve. The correlation between the stress ratio around the tip of the notch for various impact energies is shown in Fig. 11, and the correlation between the stress ratio and the impact energy for various locations is shown in Fig. 12. It may be assumed from Fig. 11 that the stress around the tip of the notch consists of a uniform stress p caused by uniform tension and a linear impact stress, p_i, caused by impact as shown in Fig. 13b. It may be assumed that the total stress of $p + p_i$ has been applied to the specimen where

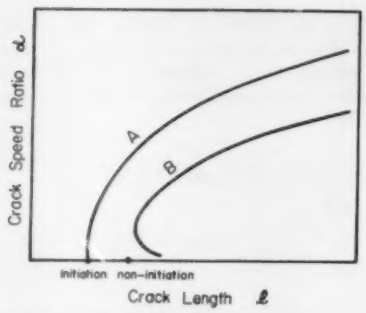

Fig. 10—l-α curve for crack initiation and noncrack initiation

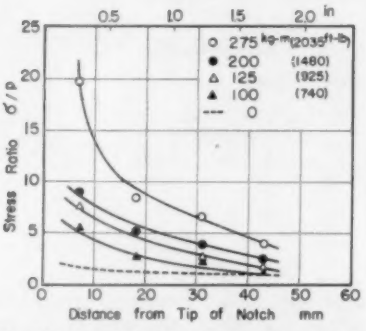

Fig. 11—Correlation between stress ratio and distance from the tip of a notch for various impact energies

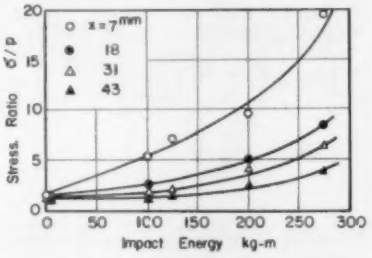

Fig. 12—Correlation between stress ratio and impact energy for various locations

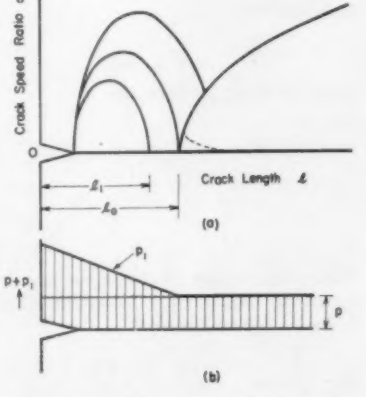

Fig. 13—Impact stress and corresponding l-α curve for the ESSO test

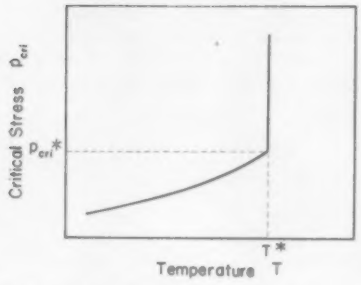

Fig. 14—Correlation between critical stress and temperature

the crack speed ratio is nearly equal to zero.

From eq 16 the energy condition is expressed by

$$\pi(p + p_i)^2 l_N/E \geqq 2S \quad (27)$$

When yielding occurs at the tip of the notch, a part of the impact energy will be absorbed by plastic deformation and the effective impact stress p_i decreases. Taking the stress in this critical condition as $\sigma_{\beta 1} \leqq n\sigma_{Yi}$ one obtains

$$\frac{p + p_i}{n\sigma_{Yi}} \sqrt{\frac{l_N}{2x_1}} \leqq 1 \quad (28)$$

where l_N is the notch depth and σ_{Y_1} is the increased yield stress due to the impact.

The critical condition in which both eqs 27 and 28 are satisfied is expressed by

$$\frac{2ES}{\pi l_N} \leqq (p + p_i)^2 \leqq \frac{2n^2\sigma_{Yi}^2 x_1}{l_N}$$

and then

$$ES/\pi n^2\sigma_{Yi}^2 x_1 \leqq \quad (29)$$

A crack cannot initiate when eq 29 is not satisfied. Equation 29 differs from eq 25 only in the term of σ_{Yi} and σ_Y.

The $l - \alpha$ curve for the propagation just after its initiation is, as well as eq 26, expressed by

$$l = \frac{2ES(1 + m\alpha^2)^2}{\pi(p + p_i)^2} \quad (30)$$

This is shown in Fig. 13a. If the impact energy is small, the corresponding $l - \alpha$ curve ends at the point $l = l_i$. Increasing impact energy will result in a greater crack length, l_i.

Meanwhile, the $l - \alpha$ curve in the region where the effect of impact cannot be found is represented by

$$l = \frac{2ES(1 + m\alpha^2)^2}{\pi p^2} \quad (31)$$

As mentioned in the preceding paragraph, this curve is shown by the dashed curve for $\alpha \cong 0$ which turns to the right (Fig. 13a) due to the yielding around the tip of the crack. The distance from the edge to the point at which propagation begins is l_0. The brittle crack can continue to propagate when l_i is slightly greater than l_0, because the initiation and propagation curves can be connected. Therefore, the following condition is necessary for crack propagation:

$$l_i = l_0 \quad (32)$$

For the case of brittle fracture without a shear lip, l_0 can be obtained from eq 26 by

$$l_0 = l_G = 2ES/\pi p^2 \quad (33)$$

For the case of brittle fracture with a shear lip, one obtains, from eq 25

$$l_0 = \frac{2ES(1.6/\sqrt{s} + \sqrt{s}/1.6)^2}{4\pi p^2} \quad (34)$$

For a constant value of l_i due to a constant impact energy, the minimum value of p or the critical stress for brittle crack propagation, p_{cri}, can be obtained from eqs 33 and 34. The $l - \alpha$ curve shifts to the right at the uniform stress p decreases, therefore, the minimum stress is expressed by

$$p_{cri} = \sqrt{\frac{2ES}{\pi l_i}} \text{ for } \frac{ES}{\pi n^2\sigma_{Y0}^2 x_1} < 2.56 \quad (35)$$

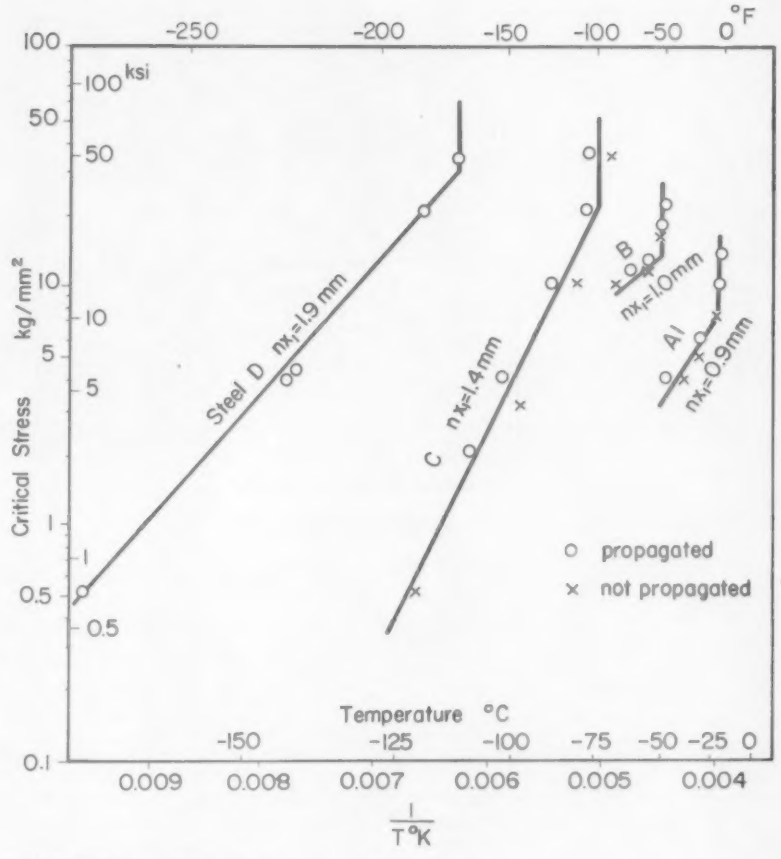

Fig. 15—ESSO transition curve

or

$$p_{cri} = \sqrt{\frac{2ES}{\pi l_i}} \frac{1}{2} \times \left(1.6 \sqrt{\frac{\pi n^2\sigma_{Y0}^2 x_1}{ES}} + \frac{1}{1.6} \times \sqrt{\frac{ES}{\pi n^2\sigma_{Y0}^2 x_1}}\right) \text{ for } \frac{ES}{\pi n^2\sigma_{Y0}^2 x_1} \geqq 2.56 \quad (36)$$

The correlation between the critical stress for brittle crack propagation obtained from eqs 2 and 35 is shown in Fig. 14. Furthermore, upper limiting temperature for brittle crack initiation, T^*, is obtained from eq 29. Since it has been assumed in this computation that $\sigma_{Yi} = 1.4\ \sigma_{Y0}$, crack propagation with a shear slip which is expressed by eq 36 does not occur. The upper limiting temperature, T^*, is called the noninitiating temperature and probably corresponds to the ESSO transition temperature. Theoretical curves with measured values for three quenched and tempered steels and one normalized killed steel, in which l_i = 80 mm (nx_1 depends on the kind of steel and varies from 1 to 2 mm) are shown in Fig. 15. The chemical composi-

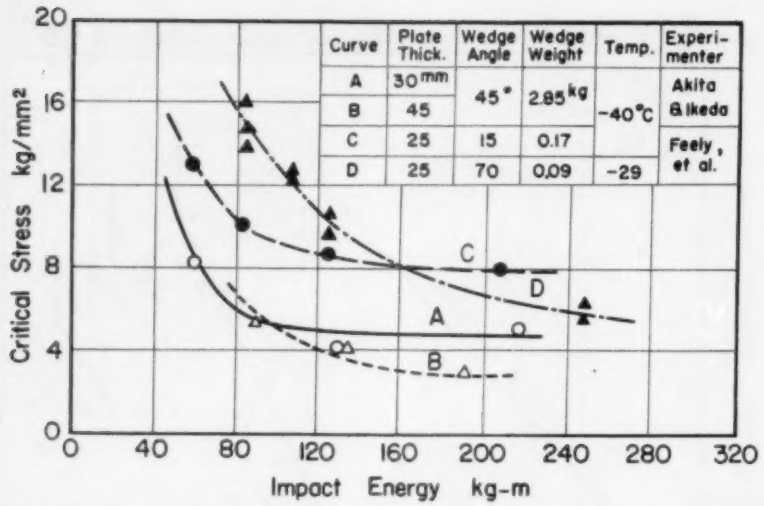

Fig. 16—Correlation between critical stress and impact energy

tions and the tensile properties of these steels tested are listed in Table 1. On this computation, the correlation between the yield stress and the temperature was taken as follows:

$$\sigma_{Y0} = Be^{K_3/T}$$

where B and k_3 are the material constants, and T is the absolute temperature. B is the constant for which σ_{Y0} becomes the yield stress at room temperature, k_3 = 176° K.

Next, let one investigate the correlations between the respective factors which are related to crack propagation. By assuming the stress distribution of p_i to be linear, the impact energy, W, is proportional to l_i^3 which is obtained by the integration of p_i^2. Since the critical stress for brittle crack propagation is proportional to $l_i^{-1/2}$, the critical stress is proportional to $W^{-1/6}$. The test results which were obtained by Feely, *et al.*[22] and the authors are shown in Fig. 16.

At the noninitiating temperature, T^*, by assuming $\sigma_{Yi} = 1.4\ \sigma_{Y0}$ eq 29 becomes

$$ES/\pi n^2 \sigma_{Y0}^2 x_1 = 2.0 \quad (37)$$

Therefore, from eqs 35 and 37 the critical stress, $p_{cri}{}^*$ at the noninitiating temperature, T^*, can be expressed by

$$p_{cri}{}^* = \sigma_{Y0}\sqrt{3.9n^2 x_1/l_i} \quad (38)$$

The critical stress is proportional to σ_{Y0} and $\sqrt{x_1}$.

In general, the quenched and tempered steel has greater x_1 and higher yield stress, σ_{Y0}, therefore its critical stress is higher. The plastic surface energy at the noninitiating temperature is obtained from eq 37 as follows:

$$S(T^*) = 2.00\pi n^2 \sigma_{Y0}^2(T^*)x_1/E \quad (39)$$

$S(T^*)$ is proportional to $\sigma_{Y0}^2 x_1$, therefore, the quenched and tempered steel will have the greater plastic surface energy.

Consequently, major factors that affect the brittleness of steel are the yield stress, σ_{Y0}, the plastic surface energy, S, and the material constant x_1 which is equal to the thickness of a thin plastic layer adjacent to the brittle fracture surface.

Construction

Brittle crack initiation and propagation have been analyzed from a viewpoint of dynamics. The theory has been applied to the ESSO test and the effect of the impact energy, the temperature, the yield stress, the plastic surface energy on the critical stress for brittle crack propagation and on the noninitiating temperature, or the upper limiting temperature for brittle crack initiation, have been obtained. The factors most affecting the brittleness of steel are the yield stress, the plastic surface energy and the thickness of a plastic layer adjacent to the fracture surface.

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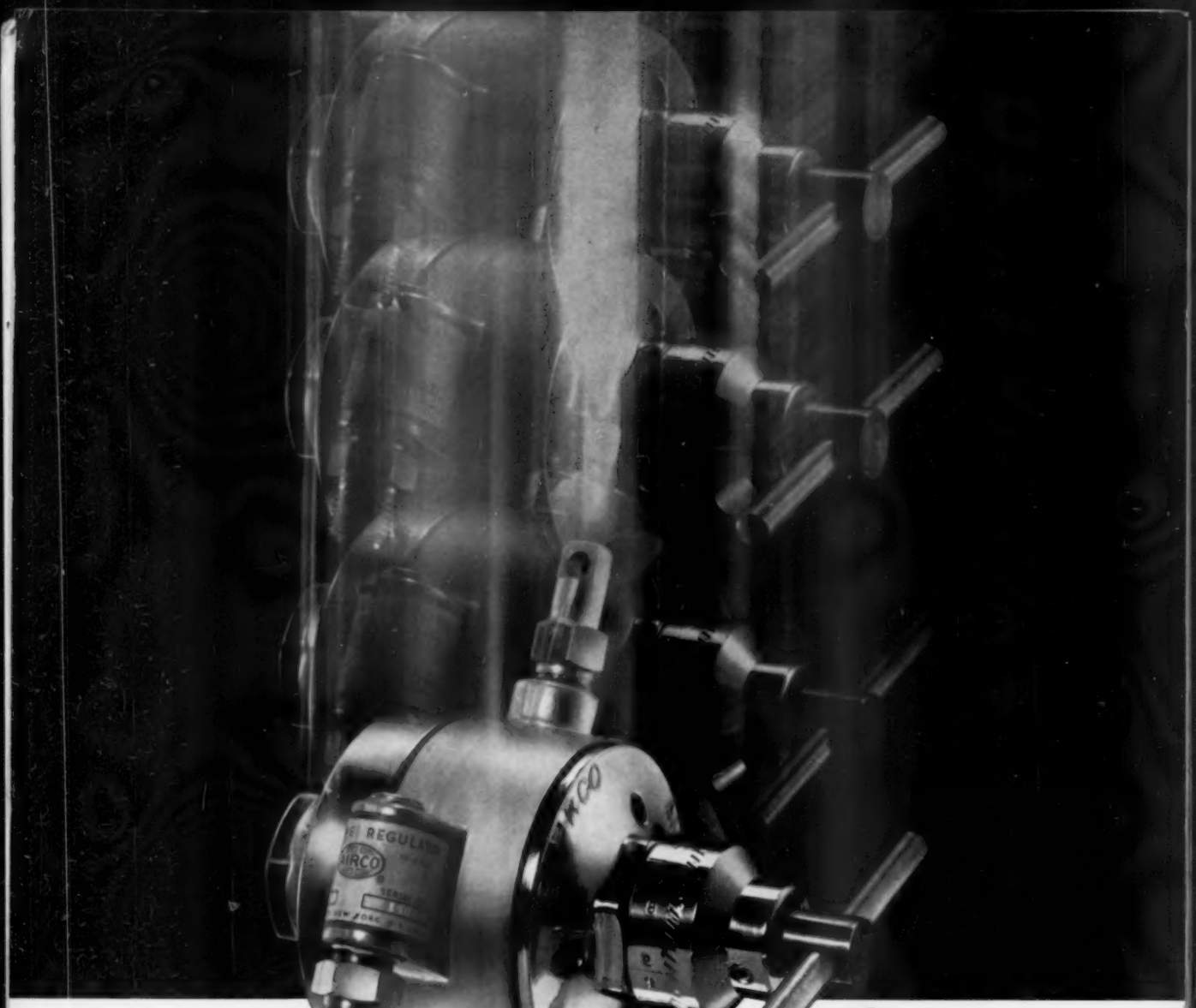

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